"AN ANALYSIS OF CURRENT ANTHROPOMETRIC TECHNIQUES IN THE ASSESSMENT OF NUTRITIONAL STATUS"

BY

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ABSTRACT

This thesis describes a very rapid survey of the nutritional state of children in a small island, Montserrat, West Indies.

The anthropometric measurements were analysed in a standard manner to show the degree to which these children were "malnourished". Comparisons with data collected by other workers in the Caribbean were used to demonstrate that the findings in Montserrat were very similar and that any further detailed analysis of the data might therefore be applicable to far larger populations.

During the course of the analysis it became apparent that the usual methods of classifying malnutrition were crude and that insufficient attention had been paid to growth retardation and a deficit in height with its attendant deficit in weight. Attempts were made to develop a new system of analysing the data by expressing the data as percentiles. This analysis proved to be too complicated for routine use and the description of standard data was too limited to permit satisfactory and internally consistent results to be obtained. However, the analysis highlighted the importance of the accurate measurements of length or height. Two studies were therefore conducted in Northampton and in London nurseries to assess the accuracy of height measurements.

The choice of cut-off points for each anthropometric measurement was critically examined and it was concluded that most workers had chosen values arbitrarily. Methods were therefore developed for establishing the appropriate cut-off points for height, weight for height, muscle and arm circumference as well as triceps skinfold thickness.

It was concluded that the major problem in Montserrat, traditionally ascribed to malnutrition in fact related to a marked deficit in height with very few children being truly wasted. Arm measurements alone were considered to be somewhat unreliable for assessing nutritional state on their own because they were relatively insensitive measures which were also particularly liable to errors.

Finally it was concluded that the timing and the organisation of the initial survey allowed measurements to be made which are sufficiently detailed for most nutritional assessment surveys.

Dedicated to:

Chloe and all the children in Montserrat and in London who made this thesis possible.

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SECTION 1

INTRODUCTION

1. 1. HISTORY AND DEVELOPMENT OF NUTRITIONAL ASSESSMENT METHODS AND ITS RELATIONSHIP TO AN UNDERSTANDING OF GROWTH.

Physical growth and development are two processes which bring the individual organism from the fertilised ovum to its final size. These processes are closely linked in time and are influenced both by genetic, nutritional and environmental factors. The term "growth" explains changes in magnitude over time in the size of both individual organs and of the body as a whole. "Development" on the other hand can take place without a change in size and refers mainly to the maturation of components of the body, presumably by the stimulation of hormonal factors or the reduced activity of growth antagonists. Throughout the history the phenomenon of human growth has interested many and research in this field has been undertaken to establish a common pattern of growth in different people as well as to identify the similarities and differences between populations living in very different environments.

Over the years it has been shown that growth depends, amongst other things, on the supply of the correct proportions of energy, nitrogen, minerals and vitamins. Energy is derived from dietary carbohydrates, fats and proteins; nitrogen from proteins;minerals and vitamins as such from the diet. A certain amount of interconversion is possible, each of these nutrients have a definite function to perform within the body. Inadequate supply of these nutrients has been shown to cause retardation of physical growth (McCance, 1951; McCance and Widdowson, 1951; Daley, 1950; Ellis, 1945; Beal, 1965) retardation of psychomotor development (Robles et. al., 1959; Cravioto, 1966; Rozovski et. al., 1971) and increased susceptibility to infection (Wills and Waterlow, 1958; Patwardhan, 1964). Due to priorities discussed above, undernutrition if not very severe can alter the shape, resulting in small and thin animals or human beings (Wallace, 1948; Hammond, 1952; Crichton et. al., 1959). It is important to note that all these effects of malnutrition have their greatest influence during the growing period of an animal or human.

A. Use of Anthropometry in Evaluation of Growth:

Methods used in the assessment of growth can be divided into two groups:

A. Chemical

B. Anthropometric

Chemical methods form the newer approach to the assessment of biological maturation. In assessing the response to treatment in malnourished children, the occurrance of growth even in the absence of gain in weight has been demonstrated by nitrogen retention (Waterlow and Wills, 1960) and by increases in the excretion of creatinine and hydroxyproline peptides in the urine (Picou et. al., 1965). These chemical methods, however sensitive they are, have a limited use in field surveys due to practical reasons.

The only tool for the assessment of growth to the average clinician is anthropometry which can be described as the technique of expressing quantitatively the size and shape of the human body, and has been used as the major tool in the evaluation of the physical characteristics of the human species. Anthropometric assessment includes evaluation of skeletal maturation, dental development, morphological size (height, weight etc.) and the age of development of secondary sex characteristics. The comparison of those measurements with known standards allows the determination of the growth and developmental status of the subject. Direct body measurement does not involve sophisticated equipment and can be done by a relatively untrained person in a very short time.

The first documented evidence on the growth of an individual dates back to the late 18th Century. During the years 1759 and 1777 Count Philibert de Montbeillard measured and recorded the height of his son at intervals and illustrated his growth not only by plotting his increasing height with time graphically but also, by analysing the rate at which his son grew. He was able to produce what we now call "distance", and "velocity" curves for his son's growth (Tanner, 1962). This is the very first documented case where anthropometry has been used to describe the phenomenon of growth.

Large scale anthropometric investigations aimed at describing the characteristics of populations and evaluating the various factors which influence these characteristics began in the second half of 19th Century. In the United States the necessity for population studies arose after the mass migrations of different ethnic groups. These groups of people, coming mainly from different parts of Europe, started to form a new group with the small number of native North American Indians and African Negroes. The American city population became heterogenous because of its immigrant characteristics. The variability of physical traits between families was high and this factor stimulated the desire to identify there variables responsible for these differences (Boas, 1923).

Franz Boas was one of the early American investigators who studied the population extensively by carrying out numerous surveys among different ethnic groups. He reported his basic findings in a classic paper on "Changes in bodily forms of descendants of immigrants" (Boas,1892). Other studies are those made by the Immigration Commission and as part of their studies the physical traits of Jewish, Bohemian, Italian and Slav families were documented (Boas, 1923).

At this time in America, there was intense interest in the physical differences between groups from different parts of the world. It had been suggested that the study of the adult population alone would not be sufficient to explain the causes determining the final form of the body. The general concern was to know what the final appearance of the nation might be if it derived its characteristics from a diverse ancestory.

It was generally assumed that heredity was the main factor influencing adult stature, but it was possible that events taking place during growth might also be important. In order to assess those factors which might influence the growth and development of children, biologists measured several groups of children, particularly those of school age group. Bowditch (1875) reported that there was a significant difference between the heights of children from different nationalities and that this difference was observed throughout the growth period. This therefore seemed to confirm the importance of genetic factors in the control of growth. However in the same study he also reported that within the same nationality there was a marked difference in the physique of children from different social groups. This finding is, as far as we know, the first documented evidence of the relationship between social class and the physical state of children in America.

After Bowditch's report, other investigators (Boas and Wissler, 1904) did similar studies in different parts of America. They used the same methods of investigation as Bowditch and found that the influence of social class on physical growth was found in all the areas studied.

These initial studies in which the anthropometric measurements of children of different ages were collected failed to provide sufficient information on the growth rate : an average value for children in each age group was calculated and a growth curve was obtained. This curve only gave an approximate rate of growth and did not show the individual variability.

Boas (1892) was the first to realise this, and it was one of the reasons for his insistence, as long ago as 1892, that long term studies on the same groups of children were needed (Tanner, 1962). He attempted to collect longitudinal data on children attending orphanages, boarding and day schools. He studied the growth rates of these children at different ages for both sexes as well as the age of onset of puberty (Boas, 1932, 1933, 1935). The data he collected included measurements of body dimensions such as weight and height together with information about their social environment. His series of children were classified according to their race or national origin. He evaluated the role of the environment by comparing the growth rates of children in the partly deprived living conditions of orphanages with those attending day schools. He documented the diet, the degree of exercise taken, the duration of rest periods and sought to analyse the influence of a stable family life and child care. By using data obtained by simple anthropo[illegible] methods and questionnaires he established the [illegible] of the scientific knowledge we have [illegible].

In Britain, unlike the United States the stimulus to research came from the discovery of the poor physical condition of young men recruited to serve in the Boer War of 1899. Growth failure in children was also recognised together with its relationship with ill health. Among volunteers for this War the percentage of those rejected for physical causes was so large that it became a subject of public discussion and concern. In 1904 a committee was established to enquire into the problem of the deterioration in the health and physique of certain classes of the population, and to determine the steps that should be taken to inform the Government about the health of the Nation by periodically collected data thus permitting an accurate comparative estimate of health and physique of the people. They also had the task of finding the general causes of such physical deterioration and to point out the means by which it could be most effectively prevented (Report of the Inter-Departmental Committee on Physical Deterioration, 1904). The evidence for the need for such an investigation was given by the War Office along with reports presented by the Royal Commission on Physical Training and the Royal College of Physicaians and Surgeons.

Even before the establishment of this Committee in 1904, some investigation of the problems of employment and labour conditions in relation to health had been undertaken in 1873, during which 10,000 men, women and children were measured and examined. Between the years 1878 and 1883 the British Association for the Advancement of Science had made a systematic survey of heights and weights with other physical characteristics of the inhabitants in the British Isles. Although these reports contained a considerable amount of information no detailed comparative evaluation was made.

Studies on children had started much earlier. After primary school education became compulsory in 1871 the general ill health of school children was recognised by school authorities and the public were becoming aware of this fact. The first serious attempt to obtain statistical information about physical development of children was made again by the British Association. A committee was appointed in 1875 to undertake an anthropometric survey of the United Kingdom. This committee issued a yearly report from 1875 until 1883. Height and weight measurements of 37,354 male and 4,816 female children of all age groups were collected. During and after this period some investigators, namely Dukes and Hall collected and reported similar information derived mainly from some Public Schools like Eton and Harrow. They tried to compare the development of these children with children from the poor East End districts of London.

In 1907 the Education Act established the need for a medical inspection of State and Secondary school children and it was laid down by the Chief Medical Officer of the Board of Education in a circular that the physical condition of the school children should be checked regularly. During the same year the medical examination was extended to include a recording of heights and weights of children. This circular and the Education Administrative Provisions Act was very important in providing basic data (Circular Number 576). From 1908 onwards the annual medical reports prepared by the school medical officers had, by law, to include tables showing the heights and weights of children analysed according to sex and age. Some medical officers classified the children according to their social class or housing accomodation and tried to relate their physical condition, growth and development to these factors (Greenwood, 1913).

Through these attempts, the relationship between the general nutritional, environmental conditions and physical growth and development had been established and the basic measurements of body dimens'ons had been accepted as the basic tool for the assessment of this phonemenon.

1.2. HISTORY OF MALNUTRITION AND ITS RECOGNITION

Throughout history there are records of severe famines caused by wars or natural disasters. In his excellent review of "Hunger Oedema", McCance (1951) reports that the first records of famine coupled with pestilence date back to the times of Heredotus (c. 450 B.C.) and Hesiod (c. 700 B.C.).

The records of the Irish Famine in 1840 and the Great Russian Famine in 1891 highlight the problems of maldistribution and the rising cost of available food. The poor classes whose purchasing power was low suffered most and large numbers of people died of starvation. Until the World Wars food shortages were almost always considered a part of epidemics, for example of typhoid, plague and dysentery. These diseases complicated the picture and were so dramatic that lack of food by itself was considered as a secondary and less important factor.

During the first World War, famine odema was seen in Poland (Budzyski and Chelkowski, 1915, 1916). Half the cases they reported were children between the ages of 2 and 10. Several German authors also investigated the degree of physical illness caused by starvation and deteriorating living conditions. They observed hunger oedema among war prisoners and those in hospitals (Jurgens, 1916; Franke and Gottsman, 1917). By 1918 food shortage had become so serious that in all parts of Central Europe the numbers of starving oedematous people had increased to thousands (McCance, 1951). In Russia also there was a series of studies on the effects of the Revolution and the subsequent Great Famine (Storfo, 1923; 1927; 1931).

The Spanish Civil War impaired the nutritional status of the nation to such an extent that it took years for adequate recovery to occur (Robinson, Jenny and Grande, 1942).

Starvation appeared as a direct result of the Second World War (Keys, et.al.,1950). In the Netherlands in 1944 acute food shortage resulted in the starvation of a large population with many deaths (The Hague, General State Printing Office, 1948). McCance and Widdowson studied the effects of War on the nutritional state of people in Wuppertal in 1946. During the War, many people had been kept in prisons and in camps where food conditions varied from tolerable to very bad and where starvation was used as a method of punishment (Keys, et.al. 1950)

Infantile Malnutrition :

In a country where famine and starvation occurs, it is expected that children and weanling infants are the most vulnerable group. However, historically there is very little mention of chronic malnutrition as a clinical entity (Garrow, 1968). There are some descriptions of starving children during the Irish famine and during the siege of Paris in 1870 (McCance, 1951). The possible reasons behind the late recognition of this clinical problem are summarised by Garrow (1968) as follows: the dominance of the vitamin deficiency concept, the ascence of scientific nutrition work and the complexity of tropical diseases. He points out that when a whole population is starving the existence of malnourished infants would not be considered noteworthy.

The first description of a disease resembling kwashiokor was made by Correa in 1906, from Yucatan Mexico. This disease was found among young children of working class families. The observed signs were gastroenteritis, pallor of the skin and skin lesions. He also noticed oedema of the legs and found that the disease was usually fatal. The name "culebrilla" mentioned by Correa was related to gastro-intestinal catarrh and the disease was considered nutritional in origin and somewhat related to scurvy (Trowell, Davis and Dean, 1954).

By the end of the 19th Century in Europe to give cereal to infants as their weanling food became the general practice especially when the child suffered from gastro-intestinal diseases. This factor can be considered as one of the main causes of the high infant mortality rate at that time. It was known that in addition to acute weight loss, there might be some pathological alterations in some organs. In 1896 Thiemich had shown fatty degeneration of the liver and in 1899 Baignsky described a disease called "atrophic marasmus of nursling", this syndrome was prevalent in institutions. He emphasized the negative nitrogen balance and the marked atrophy of the intestine. It was around the same time as Correa's report from Yucatan that Czerny and Keller described a disease called "Mehlnahrschaden" (1906) among children suffering from acute gastro-intestinal upset in Germany. This report is considered as one of the first detailed analyses of a Kwashiokor-like syndrome in Europe. The authors thought that the disease was due to an excess of flour in the diet. Later in 1928 these authors produced an account of this disease with social and dietary information. Gastro-interitis was considered fatal and other clinical signs observed were related to the gastro-intestinal problems. Nicleeff (1923) examined the livers of wasted and oedematous children and found marked differences with athropic cells in the wasted and fibrous fatty condition in the oedematous group. From these studies it becomes obvious that wasting due to starvation was known and attempts were made to relate odematous conditions to nuttitional deficiencies, especially of protein.

Reports from Africa: Kwashiokor

In Kenya, Philp (1925) and Proctor (1925, 1926) reported a severe odematous disease in children. They related their findings to the presence of parasites in the stool. Although treatment for the parasites failed to improve the condition neither author suggested that the origin of the disease might be nutritional. From the Gold Coast Dr. C. Williams (1931, 1932, 1933) described a disease which she named "Deficiency disease in Infancy" and gave a full description of this syndrome with details of the age of incidence, skin changes, oedema, apathy and fatty filtrous liver. She thought that these clinical findings were due to an insufficient diet which was mainly based on maize gruel. She was convinced that the disease was malnutrition because cure was achieved by continuous breast feeding supplemented with skim milk (Trowell, Davies and Dean, 1954).

About 1934, Stannus (1934), who had studied pellagra in

Nyasaland, criticised the findings of Williams and thought that the disease was Pellegra and based his arguments on the skin lesions (dermatosis). Loewenthal (1933, 1936) from Uganda, Sequeria (1937, 1938) in Kenya and others agreed that the dermatosis was certainly pellegra. In 1935, however, Williams reported that she had found 60 more cases suffering from the same ailment and that the local name was "Kwashiokor". This disease was certainly not due to Vitamin B complex deficiency alone. Continuing her studies in Malaya, Williams (1938) stated that the unsatisfactory growth was due to malnutrition which was caused by a diet rich in bulky carbohydrates and deficient in proteins and fats.

Meanwhile Trowell (1939, 1940, 1941) had summarised other reports of similar kinds of clinical findings from different parts of the world and stated that nutritional factors ought to be considered seriously because the most common clinical finding of kwashiokor-oedema had been related to acute protein deficiency in the diet. He concluded that this disease was most probably due to multiple deficiencies.

During the next 20 years, this disease was recognised and described in almost every part of the developing world.

1.3. ASSESSMENT OF NUTRITIONAL STATUS OF HUMAN GROUPS

The methods used for the assessment of nutritional status of human groups are discussed by Jelliffe (1966) in great detail in his Monograph.

These methods are divided into 3 main groups:

1. Direct nutritional assessment methods.
2. Indirect nutritional assessment methods.
3. The assessment of the ecological factors.

In this section we are going to discuss the direct assessment methods and we will be mainly concerned with nutritional anthropometry. The direct nutritional assessment methods can be summarized as follows:

1. Clinical signs.
2. Nutritional anthropometry
3. Biochemical tests.

One of the purposes of this thesis is to assess the validity of nutritional anthropometry methods in relation to the identification of mild and moderate forms of malnutrition. Therefore, we are going to concentrate on the nutritional anthropometry as a direct assessment of the nutritional status.

As we have pointed out in previous sections, malnutrition results in growth retardation. Nutritional anthropometry appears to be of greatest value in the assessment of growth failure and undernutrition particularly from lack of protein and energy.

The joint FAO/WHO Expert Committee on Nutrition, 1951 stressed the relationship between bodily dimensions and nutrition and pointed to the need for anthropometric data obtained with agreed methods and standards (WHO Tech. Rept. Ser. No: 44, 1951). The fourth session of the Joint FAO/WHO Committee again emphasized these points (WHO Tech. Rept. Ser. No: , 1955).

In 1955, a committee on Nutritional Anthropometry of the Food and Nutrition Board of the National Research Council of America met and made recommendations concerning body measurements for the assessment of nutritional status. These recommendations can be summarised as follows:

1. The need to select a few measurements only.
2. The need to use standard techniques in measurement.
3. Standard equipment to be used.
4. Data to be compared with reference standards.
5. Standardised recording of the measurements.
6. Uniform reporting of the measurements.

A. Nutritional Anthropometry and the Problem of Age Assessment:

For nutritional anthropometric measurements to be meaningful the correct age of subjects should be known. Especially for infants and pre-school children a more exact age assessment is necessary because growth is closely linked to time. However in many parts of the developing world the exact age of the children is usually not known. Within such communities various methods of age assing approximately has been suggested (Jelliffe, 1961 b; Tukei, 1963).

These methods are:

1. The use of local calendars based on events in the preceding years including agricultural, climatic and political occurances as well as natural disasters.

2. The time for the eruption of the decidious teeth. The validity of this method has been widely discussed by many authors (Jelliffe, Graham and Morales, 1963; Welbourn, 1956; McLaren, Ammoun and Houri, 1964).

3. The presence of older or younger siblings or a pregnant mother may also provide useful information in estimating the age of the individual under observation. The best method of age assessment may in practice need a combination of all these methods.

To overcome the problem of assessing age, attempts were also made to develop age independent indices such as weight for height, weight over height^2 etc.

B. The Most Commonly Used Body Measurements For The Evaluation of Nutritional Status:

The number of possible body measurements are unlimited (Brozek, 1956). For field surveys the aim is usually to employ the simplest and quickest methods and those most easy to reproduce to give the maximum information concerning the particular nutritional problem under investigation (Jelliffe, 1966). The most commonly used measurements are those made to assess:

(a) body mass, as judged by weight,

(b) linear dimensions, especially height or length; and

(c) body composition for example indices of the reserves of energy and protein as judged by the principal superficial soft tissues, subcutenous fat and muscle.

Weight is accepted as the key anthropometric measurement. It is a composite measurement, since it does not only reflect body fat but a combination of the weights of the skeleton, muscle mass, fat and water. Therefore the evaluation of the significance of weight measurements must take into account length, frame size, proportions of fat, muscle and bone and the presence of pathological weight due to oedema or splenomegaly.

In addition, weight measurements may be combined with other appropriate measurements and with clinical examinations (Jelliffe, 1966 ; Seoane and Latham, 1971; Waterlow, 1973).

Height as a linear measurement is considered as one of the best indicators of growth. Any serious growth retardation would show itself by a considerable deviation from the mean height or length at a specific age (P ough, 1962).

In growth and development studies as well as in the assessment of nutritional status within the community, arm circumference is widely used giving information parallelling body weight. Both Gurney (1969) and Rutishauser (1969) as well as many other workers reported that the distribution of arm circumference for age results suggests that this measurement is as good an indicator of the nutritional status of the population as is weight for age and weight for height and correlates well with both of these indices.

Arm circumference is made up of bone, muscle, fat, and the blood and lymph vessels and their contents; extra cellular fluid and the skin. As a composite measurement, it has been recognised as providing useful informat on about the sub-cutenous fat as well as muscle mass. When the ages of children are not known arm circumference may represent a simple, practical, age-independant and composite measurement related to growth failure and to protein depletion and energy reserves that can give information in community surveys, in screening in emergency feeding services or in ranking the public health priority in villages (Jelliffe,1969).

Triceps skinfold thickness, as one of the skinfold thicknesses has been used to give an indication of body fat (Hammond, 1955). Usually a combination of skinfold thickness measurements collected from different sites of the body are used as an indicator of the total body fat (Durnin and Rahaman, 1967; Durnin and Womerley, 1974, Pollock et. al., 1975).For the assessment of nutritional status under field conditions only triceps skinfold measurement by itself is not very meaningful and may be subject to error, it is still an index which gives an estimation of the energy reserves of the body.

The muscle circumference measurement is very important in relation to the assessment of protein energy malnutrition.

Muscle as the largest protein containing organ in the body is often depleted in malnutrition. Standard, Wills and Waterlow (1959) showed the decrease in muscle mass as calculated by both external measurements and radiography. Muscle was reduced by up to two thirds and this reduction was greater than the deficit in body weight in malnourished babies in Jamaica. Body fat and protein from muscle is used to provide energy in order to maintain constancy in the internal environment.

The fat free arm circumference is a combined measurement of bone and muscle and can be calculated from the arm circumference and triceps skinfold thickness. The formula used is as follows:

$$\text{Muscle circumference} = \text{Arm circumference} - \text{Triceps skinfold} \times \pi$$

The assumption is made that the diameter of the humerus is relatively constant, so that it can be included with the muscle mass (Seoane and Latham, 1971).

I.4. ASSESSMENT OF NUTRITIONAL STATUS IN THE FIELD

A. ICNND Surveys:

The Interdepartmental Committee on Nutrition for National Defence was established in 1955 to investigate the nutritional state of people living in developing countries. The aim of the project was to carry out integrated studies with an assessment of the agricultural, economic, cultural and technological capacity of the country to deal with its nutritional needs. Such a multidisciplinary study can then be used as a basis for planning by governments as well as international and private organisations (Wilson et. al., 1964).

ICCNND surveys were planned to cover a large population in both military and civilian life and those in rural and urban areas and in adults as well as children. In every country the sample of people surveyed selected to represent geographic and ethnic differences, known dietary deficiencies, age and occupation. The total sample of 10,000-6,000 people underwent a simple form of examination. Within this group 3,000-2,500 were investigated in more detail; in addition biochemical and other medical tests were carried out on 500-600 people.

These surveys played an important role in the development of nutritional survey work. Some of the omportant results of these surveys are as follows:

1. It became quite clear that nutritional problems are multicausal and if reliable information is to be collected for further preventive purposes then the studies must be multidisciplinary.

2. The use of identical survey techniques in providing comparable information for groups in the same country or different countries.

3. A manual for nutrition surveys (ICNND Manual for Nutrition Surveys, 1963) was prepared by ICNND team members to serve as a detailed guide. This manual covers almost all aspects of a nutrition survey including clinical, laboratory, dietary work and sampling techniques as well as forms for records. It is widely accepted and used as a handbook by many other investigators working on surveys other than ICNND projects. These surveys were done in countries like Thailand Burma, Malaya in the Far East, Turkey, Lebanon, Iran and in other Middle Eastern countries, in Ethiopia and in some Latin American countries like Venezuela, Bolivia and Uruguay (Schaeffer, 1958; Wilson et. al., 1964).

The host country where the survey was carried out assigned some medical personnel to take part in the survey as team members. These people were trained by the ICNND staff. The native members of the survey team were chosen specially so that they would continue with nutritional work in their country.

Within 8 years, heights and weights of over 15,000 children under 6 years of age in 17 countries were collected. These studies were all done on a cross sectional basis.

b) INCAP Surveys:

INCAP was established in 1949 with the collaboration of 6 Latin American countries to study the nutritional conditions of the populations of Central America and Panama. In its early years, INCAP made a series of dietary, clinical and bio-chemical studies throughout the area on a small scale and provided initial information on the nutritional problems in that area (Scrimshaw, Behar, Perez, Viteri, 1955). As in ICNND studies the aim was to collect information by using identical methods of assessment.

In 1960 with the help of ICNND, INCAP carried out a large scale study by surveying 1-4 people per 1000 population in 6 countries of Latin America. Both the ICNND and INCAP investigations included a clinical examination, anthropometric measurements, bio-chemical and hematological examinations, immunological and parasitological tests, dietary surveys and an analysis of the environmental characteristics in the socio-economical, agricultural, food industry and food technology spheres. Apart from these, INCAP studies included a bone maturation and development study (Nutritional Evaluation of the Population of Central America and Panama, Regional Summary, INCAP, 1965-1967).

These large surveys are examples of the way in which the emphasis on community aspects of malnutrition became apparent during the 1960s.

1.5. THE CRITERIA USED IN THE ASSESSMENT OF NUTRITIONAL STATUS IN THE FIELD

Jelliffe et. al. (1960) carried out a nutritional survey to measure the public health significance of malnutrition in early childhood in Haiti on a country wide basis. They employed three different methods of assessment. These were:

1. Clinical signs: the children were classified into 4 groups according to the clinical pucture they presented. a. kwashiokor, b. incomplete kwashiokor, c. nutritional marasmus and d. nutritional dwarfing.

2. Nutritional indices: those were a. oedema, b. arm muscle and fat measurements, c. hair changes .

3. Assessment of body weight: for this Gomez classification of 1st., 2nd., and 3rd. degree body weight loss was used.

According to the first method of assessment of prevalence of kwashiokor, incomplete kwashiokor, nutritional marasmus and dwarfing was found to be 7 %, 10 %, 3 % and 7 % respectively. The oedema index (from the 2nd. assessment method) gave a prevalence figure of 7 % for the total group. Despite the fact that other pathological conditions such as nephrotic syndrome would be included in this group, all children who had oedema were found to be suffering from kwashiokor.

Arm circumference and fat measurements from this group were compared with values obtained from "normal" healthy Jamaican children and 80 % of average Jamaican figures were accepted as cut off points. According to this criterion 69 %

of the Haitian group was found to have low arm circumferences and 67 % had low muscle circumferences. The hair pluckability index gave a prevalence of 52 % for the total group. These "malnutrition indices thus gave very much higher prevalence rates for malnutrition than those based solely on clinical signs.

For the body weight classification, Jamaican "normal" weight values were used as the standard. Age assessment proved to be difficult and detailed questioning about the date of birth by reference to a calendar of local events helped in determining the ages. According to this classification 37 % had first degree , 21 % had 2nd. degree and 3 % had third degree malnutrition. Jelliffe and his co-workers discussed the value of the three different methods of assessment and suggested the use of a combination of oedema with a weight classification and an index based on arm circumference to determine the prevalence of malnutrition under field conditions particularly when large numbers of children had to be surveyed. Their major conclusion was that where the prevalence of kwashiokor was found to be 7 %, the mild and moderate forms of malnutrition were present in even greater numbers within a community. This study was important in that it drew attention to the mild and moderate forms of malnutrition occuring much more frequently than the severe cases of kwashiokor or marasmus.

Similar types of surveys were carried out by Jelliffe in different parts of Africa where malnutrition was expected to be prevalent. They surveyed the Kigezi district in Uganda, (Jelliffe et. al., 1961a) and Lugbara and Acholi children in the West Nile District of Uganda (Jelliffe et. al., 1962a; Jelliffe et. al., 1963). The results of another survey conducted by Jelliffe in Southern Trinidad in 1960 showed relatively less malnutrition in the community at the time of the survey and oedema among pre-school children was almost non-existent. For the evaluation these results they employed two different standards; one standard based on measurements of local children of both African and East Indian descent and also the Boston standards. The weight for age classification was used to identify the malnourished group. When the children classified as malnourished according to these two different standards were compared,no difference was found in the proportion with 3rd degree malnutrtion but a 10 % difference was found for the 1st. degree group (Jelliffe et. al., 1960). The use of the Boston standard increased the number of those diagnosed as having 1st. degree malnutrition.

Kondakis et.al., (1964)surveyed three regions in Tanzania where they examined 799 randomly selected children from 6 to 36 months of age to assess their nutritional status by rapid clinical and anthropometric methods. The anthropometric data collected were height, weight, skinfold thickness and arm circumference. Their aim was to use the minimum number of signs and measurements to detect malnutrition. They used

Baganda standards for the comparison of height and weight measurements (Dean and Jelliffe, 1960). The weights were categorized into four groups. About 45 % of the children were grouped as having 1st degree malnutrition. When they compared average heights with Baganda standards it became obvious that the children classified as having 1 st. degree malnutrition were also shorter. For skinfold thicknesses and muscle circumference a specific standard was not used for comparison, instead a cumulative frequency curve for muscle circumference was plotted and for both of these parameters regional comparisons were made. They concluded that muscle circumference could also be a good index of protein energy malnutrition.

During this period therefore it became accepted that weight was an important index of malnutrition but the additional measurements, particularly of the arm could be useful.

I.6. CLASSIFICATION OF PROTEIN ENERGY MALNUTRITION

A. The need for an internationally accepted classification:

The 8th Joint Expert Committee on Nutrition emphasized the need for an accepted classification and definition of protein energy malnutrition (FAO/WHO Tech. Rept. Ser. No. 477 1971). Although there were many surveys, the absence of internationally accepted criteria creates difficulties in interpreting the available information (Bengoa, 1970). In order to establish preventive measures, the prevalence of this nutritional deficiency syndrome should be known.

The difficulties involved in establishing a classification are grouped by the 8th FAO/WHO Expert Committee are as follows:

1. Protein energy malnutrition is multicausal in origin.

2. For mild and moderate cases there is no clear cut division between the pathological and the normal conditions.

3. Infections alter the pattern of malnutrition.

4. The most common feature of PEM both in severe, mild and moderate cases was the degree to which children failed to grow. The Committee advised that the choice of classification should depend on the purpose of investigation. Waterlow (1971) pointed out that with severe cases of PEM a qualitative classification is needed to distinguish patterns of malnutrition in children admitted to hospital whereas a quantitative classification is needed in community studies of prevalence of severity.

B. Classification of Severe Forms of PEM

The severe forms of PEM are grouped according to the pattern of the syndrome. It is generally accepted that among children suffering from severe PEM the clinical picture presents a continuous spectrum. There is a good deal of evidence that the same applies to many of the bio-chemical features; for example, in "marasmus" the plasma albumin level although higher than in "kwashiokor" is usually well below normal and the body water content may be increased in the absence of oedema (Viteri et. al. 19). In some cases of marasmus there may also be a moderate fatty infiltration of the liver. Therefore it seems clear that even among these features there is no complete separation of the two ends of the spectrum.. Many workers suggested that the term protein energy malnutrition covered the whole spectrum and there was no need to try and distinquish kwashiokor from marasmus. However one reason for continuing to maintain a distinction is the unsolved problem of the extent to which these sy dromes represent different casual processes.

Different workers have attached special significance to one or other of the clinical features which produces this syndrome to which Cicely Williams gave the name kwashiokor. Trowell (1939) laid stress on the dermatosis, Waterlow (1948) on the fatty liver and hepatomegaly, Brock and Autret (1952) on the red hair. None of these became accepted as the main diagnostic criterion. It is now accepted that these signs change from one area to another and reflect regional differences in the clinical pattern. However, there is a general agreement that oedema must be present for the diagnosis of kwashiokor.

Garrow (1966) analysed 327 severely malnourished children in Jamaica and primarily used weight for age to classify the cases. His criteria were as follows:

i. No child was considered to be severely malnourished unless he was below 70 % of the expected weight for age.

ii. The criteria for kwashiokor were : a child at minimum weight of not less than 60 % of expected weight for age; oedema present, plus either hepatomegaly or dermatosis.

iii. The criteria for marasmus were that the child should be less than 60 % of expected weight for age, and have no oedema or other specific signs.

iv. Children who were less than 60 % of expected weight, with oedema or other signs were classified as the intermediate form (marasmic kwashiokor). These formed the largest group, nearly 70 % of all cases.

Table I. 6. 1.

Classification of Malnutrition as Suggested by Garrow

Severely Malnourished	Kwashiokor	Marasmus	Marasmic-Kwashiokor
Below 70% of expected weight for age	Not less than 60% expected weight for age	Less than 60 % expected weight for for age	Less than 60 % expected weight for age
	Oedema plus Hepatomegaly or dermatosis	No oedema or other specific signs	Oedema or other specific signs

McLaren et. al., (1967) suggested a scoring system for PEM based on the statistical analysis of clinical features and bio-chemical changes. A score was given to oedema, dermatosis, hair changes, hepatomegaly, serum albumin and total protein levels. The theoretical range of scores were between 0 – 15. A low albumin level rates a high score and on this score-scale, a child with marasmus could have a score between 0 – 3, an intermediate case 4 – 8, and a child with kwashiokor 9 – 15. There was a continuous spectrum of bio-chemical changes with values approaching normal as the score diminished. This scoring system does not measure the severity of malnutrition but it indicates the shift of the spectrum in severe cases from marasmus to kwashiokor. McLaren et. al., accepted oedema as the major clinical sign. this classification is not considered very practical for international comparison for it depends on laboratory measurements which may not be available under field conditions. The problem of comparing laboratory findings obtained by different workers and having different methods also becomes important.

Another simple and useful classification was proposed by a working party - Wellcome Party- which met in 1969. The classification suggested by this group is quite similar to Garrow's. According to this classification (Wellcome Classification, 1970) both the serverity and the type of the syndrome can be identified because it employes weight for age and oedema as criteria. The expected weight for age is taken as the 50th percentile Harvard Standard. The point where malnutrition begins was defined as a reduction in body weight below 80 % of the 50 th percentile; a child is considered marasmic if his weight for age is less than 60 % of the expected weight for age without oedema. The diagnosis of marasmic-kwashiokor would be applied to those who are less than 60 % of expected weight for age but have oedema. The term kwashiokor would apply to the children who have oedema and are between 80-60 % of expected weight for age. The general characteristics of this classification is given in the following table.

Table 1.6.2.

The Wellcome Classification

	Body weight, as percent of standard weight for age	
	80-60 %	Less than 60 %
Oedema present	Kwashiokor	Marasmic-kwashiokor
Oedema absent	Underweight	Marasmus

Although oedema is accepted as the cardinal clinical sign of kwashiokor, from the strictly scientific point of view this may may not be justified for children with marasmus as well as kwashiokor who have increased amounts of body water (Waterlow, and Alleyne, 1971).

This classification is simple to use and allows international comparisons to be made without much difficulty. Its disadvantages are twofolds: firstly the age of the child must be known, and secondsly, comparisons are made with an international standard and therefore reflect any further differences.

c. Classification Used in Community Surveys.

a. Classifications based on Weight for Age

Gomez et. al. (1956), working in Mexico, deviced a method of classification of malnutition in children between the ages of 1 and 4 years. The original purpose of this classification was to group the cases of similar prognosis and to guide physicians in selecting a place for treatment. This classification of malnutrition according to its varying degrees of severity was neither intended for older children nor for field surveys to determine the prevalence in a given community. Gomez based his classification on weight deficit for age. The weight of the child was expressed as a percentage of the standard weight for age and Gomez et. al. used Mexican standards for this purpose. Because of its practicability it has been widely accepted and used as one of the major assessment methods. The main features of the Gomez classification are shown in Table I.6.3.

Table I.6.3.

Gomez Classification

Degrees of Malnutrition	Body weight as % of standard
First degree	90-76
Second degree	75-61
Third degree	60 and or below

By definition this classification is simple. However, there are disadvantages in the application because there is a need to know the age of the child as well as an appropriate standard. In developing countries where PEM is highly prevalent, due to cultural and educational factors the birth registers are either incomplete or the age of children are not known by their parents accurately. Jelliffe et. al. (1961 b) proposed that local calendars should be constructed but the accuracy of this classification based on a hyphotetical age grouping then becomes questionable.

Gomez originally had used a local Mexican standard for the comparison of weight measurements, the need for an internationally accepted standard was emphasized and Harvard Standards (Stuart and Stevenson, 1959) were accepted as the criteria for comparison.

Gomez et. al. (1956) studied the mortality rate among their patients and reported that differences in weight have a significant effect on mortality independent of cause of death. There was a marked difference in mortality during the first 48 hours between children with second degree malnutrition and those with third degree. They concluded that the classification of malnutrition by degrees of weight deficit for age has clinical value as well as prognostic significance. Although widely criticised, this classification has been widely used in clinical and field studies. One of the criticisms about this classification is its insensitivity in detecting mild and moderate cases. In the community the number of severe cases of PEM is fewer compared with the moderate and mild forms. Another major criticism of this classification is that weight loss is the criterion used to identify the malnourished from nourished but the presence of oedema and severe infections unless very carefully excluded might lead to a wring conclusion. It was suggested that all cases with oedema should be considered as third degree malnutrition (Bengoa, 1970). In practice this additional requirement is not necessary because in a community where mild and moderate forms of PEM is prevalent children with oedema are not very common.

Another problem with the Gomez classification is that even though children who had been treated successfully are still underweight for age, and they might not reach the normal range and continue to be classified as malnourished.

b. Modifications on Gomez Classification:

Wray (1961), and Wray and D Ara (1964) adapted the Gomez classification and put it in a graphical form by drawing curves for various levels of weight deficit. Simply by plotting the observed weight against the age of a given child, the nutritional status of that child could be directly read.

Wray and Auirre (   ) measured the heights and weights of 1,094 children under 6 years of age in Candelabra, Colombia. They evaluated the results by Gomez classification. Mexican standards, where 50th percentile value is equivalent to the 25th percentile Harvard standards were used for comparison. Apart from the 3 degrees malnutrition which classified the severely malnourished children they deviced 2 further categories to be more sensitive in detecting the mild and moderate forms of PEM. Children above 50th percentile Mexican standard weight for age were grouped under the heading of " normal plus " and children below 50th percentile but above 85 % of 50th percentile were grouped as "normal minus ".

Jolliffe (1966) proposed a classification similar to Gomez where the intervals for weight for age are subdivided as 90-80 %, 80-70 %, 70-60 % and less than 60 % of the standard. He employed Harvard standards for comparison. The advantage of this subdivision method is that the standard deviation of weight for age is about 10 % of the mean value at ages 0-5 years so that each group represents 1 standard deviation and this method of grouping can be considered more sensitive than original Gomez classification.

Developmental Quotient:

Graham (1968) introduced the "developmental quotient" which relates the developmental age to the chronological age.

Instead of expressing weight as a percent of the standard for that age, he calculates the "developmental age" of the child as the age of a standard child of the same weight. The ratio of developmental age to chronological age is the developmental quotient (DQ). A DQ for height can be calculated in the same way and is then directly comparable with the DQ for weight, because the units are the same. Since weight is a cubic and height is a linear measurement the comparison made between percent of expected weight and percent of expected height is not the same as the comparison of DQ for height and DQ for weight. The application of DQ for assessing malnutrition in the first year of life is difficult, because severely malnourished children under 1 year of age may have a body weight which is close to or even below the normal birth weight. To be able to apply DQ to assess such cases one has to calculate both the chronological age and developmental age from conception rather than birth (Waterlow and Rutishauser, 1974).

d. Classifications based on Height for Age:

Until recently, the height measurement was not considered important in terms of classification. A common feature of PEM is growth failure, the wasting of body fat and muscles and weight deficit alone was thought to be a good indicator. On the other hand, height reflects linear growth and height gain is progressive unless retardation in growth results from mlanutrition.

The 8th FAO/WHO Nutrition Expert Committee emphasized the importance of height or length measurement since the extent of height deficit in relation to age may be regarded as an index of the duration of malnutrition.

Although in almost all of the growth studies height measurements were used as an index of growth, until the 8th report of the FAO/WHO Committee, little emphasis was put on the use of height measurement. Seoane and Latham (1971) and Waterlow and Alleyne (1971) discussed the concept of the duration of malnutrition and suggested weight for height as an index of current nutritional status whereas the index height for age indicates the past nutritional history. This later paper, however, was published after the work detailed in this thesis has begun and the nature of further classification of malnutrition will be discussed in relation to our data to illustrate the meaning of present trends in this field.

1.7. STANDARDS OF REFERENCE

The most useful and widely accepted method in the assessment of nutritional status is the evaluation of growth and comparing it with reference standards (Jelliffe, 1966). The standards of reference are usually derived from samples of well nourished children of Caucasian origin in developed countries (Habicht et.al., 1974).

The widespread use of growth standards is based on the assumption that physical size can be used to assess health. This assumption implies that every child not only has an "inherent growth potential" which will under optimal conditions be reached but the method also assumes that the child's growth is predictable. If the child is living under adverse environmental conditions and stress, then he will not be able to attain his optimal size.

The use of standards have been summarised by Tanner and his co-workers as follows:

1. Whether a particular child's height or weight is within the normal range for his or her age, sex and socio-economic group; whether his rate of growth over a period is within normal limits and whether any treatment given has produced any change in the rate of growth.

2. Whether the mean heights and weights of groups of children fall within the normal limits. This will help the public health officers to keep a close watch on the growth of children and introduce any nutritional programmes when necessary (Tanner et. al., 1966).

The data for standards are collected by three methods: these are longitudinal, mixed longitudinal and cross section-al studies carried out on healthy populations. In a cross sectional study, large numbers of different children are measured only once at different phases of their growth. On the other hand in a longitudinal study the same group of children are measured at defined age intervals over a time period more than once during their growth.

In practice, it is difficult to carry out a pure longi-tudinal study, as over the years the number of children included in the study decrease; some subjects leave and others join in. Then this study becomes a mixed longitudi-nal(Tanner, 1958). The majority of the studies began longi-tudinally have in practice become mixed longitudinal and the results then are calculated by special statistical procedures to obtain information about growth velocity and to estimate the variability of velocity from one year to another. They suffer from the disadvantage that they are lengthy, costly and dependent upon the continuous co-operation of the subjects (Tanner, 1958). Growth velocity only can be obtain-ed by the longitudinal method and this approach is favoured in assessing nutritional or other effects on health because it is considered to be a sensitive diagnostic tool in the assessment of malnutrition or growth retardation due to environmental or congenital, endocronological factors.

Although cross sectional and longitudinal studies do not give the same information, cross sectional method has some advantages such as being less costly, very practical and rapid. These studies tell us about the distance curve of growth, that is the height or weight attained at a particular age. This type of data has only limited usefulness in the constructing of velocity curves. The rate of growth from one year to another can be arrived at by subtracting the mean value at one age from the other, but this gives only a rough idea. However, cross sectional studies which represent static measurements can be useful in providing information about secular changes which take place over a long time span within the same population (Van Wieringen, 1972).

The fundamental method of preparing growth standards is by grouping the growth data as means and medians with percentile limits at each defined age.

"The average" which is the measure of central tendency can be expressed as either the arithmetic mean or median. In the preparation of growth standards the median value has the advantage since the distribution of biological characteristics is often not strictly normal and may be skewed as, for example for weight distribution. Thus the median is more informative particularly when dealing with fairly small numbers (Falkner, 1962a).

Jelliffe (1966) has recommended the use of local standards for comparing the nutritional status of members of a community with "normal" values from well nourished individuals of the same genetic stock. As Jelliffe himself admits, however, a number of criteria should be met before a group of children can be considered appropriately nourished to serve as a reference .

Some of the standards which might have been used for comparison will now be dealt with briefly.

The British Standards:

Tanner (1958); Tanner and Whitehouse (1959) published standards for height and weight of British children. Their sample was limited to children from London and Oxford. These standards were based on data collected longitudinally from 80 children of each sex and combined with cross sectional data collected from 1000 children of each sex at each age group. Tanner et. al. reported that although their longitudinal group was very small,they observed velocities of growth which agreed with other data from Switzerland, Edinburgh and Oxford. More recently Tanner et. al. (1966) discussed the needs for a newer British Standard due to the secular changes in height and weight in the community and presented new standards for distance and velocity, based on,for the most part, London children measured in 1959 the values being "adjusted" to the values expected to apply to in 1965.

Harvard (Boston) Standards:

These old North American standards, published by Stuart and Stevenson (1959), are the most widely used and accepted international norms for comparison with children in developing countries. These standards were prepared on data collected longitudinally from birth to 18 years. In all there were 220 children, 111 boys and 113 girls. Great care was taken with this study and even the mothers were under observation from the 3rd month of pregnancy. Children were examined very carefully from birth and followed medically and anthropometrically.

Only lower middle class families living in Boston of North American and European origin were included in the study and despite the economic depression of the 1930's the families were considered to have a reasonably good family and social environment. The group was randomly selected, the objective in selection was rather to obtain a relatively homogenous group so as to eliminate extremes of differences due to different racial stock, economic status and social influences. The children were under special surveillance throughout the study with all their illnesses recorded and treated by the study centre. Cases with congenital defects, those who moved from the city or and those who died were all excluded. The examinations were carried out within a fixed number of days of the actual age intended. The limits of variation in age examination was ± 48 hours at birth to ± 20 days at 78 months. Very detailed clinical examintaion, anthropometric measurements, X-rays, pediatric interviews were also made during this period.

Harvard standards were given in 3 monthly intervals up to 18 months of age and in 6 monthly intervals up to 18 years. This longitudinal data was expressed both as median values and as values corresponding to seven percentile ranges. Although these standards are sometimes considered to be out of date or in some way "old-fashioned" it should be obvious that the reason why they are so widely used is the extraordinary care which went into the selection and measurement of these children. These standards therefore represent an important body of work which should not be discarded lightly. A frequently quoted disadvantage is the possibility that they may not be relevant for other populations of different ethnic origins.

Dutch Standards:

J.C. Van Wieringen (1972) reported secular changes in growth together with data which formed the basis of the Dutch height and weight standards. The initial part of the survey was carried out from 1952 to 1956 and led the authors to believe that a secular growth shift were occurring which might have continued after 1955. As a result, from 1964 to 1966 a series of height and weight surveys were made in three populations to document the secular trends during the previous 10 years. The study also aimed to provide a revision of the existing standards. There are other similar studies reported for other countries but the reason for selecting the Dutch data for special mention is that they are based on a very large number of subjects and the information has been very carefully prepared with analyses of the weight distributions at each height in children of different ages.

These advantages will become apparent later when discussed in following sections. The sample of Dutch standards were consisted of :

1. A nation-wide representative sample of 0-24 year olds with nearly 55,000 people measured in all.

2. Conscripts of the 1967 draft and recruits of 1966 as well as previous drafted men were measured.

3. Male and female students from the State Universities were also included.

This study also represents an enormous amount of work and we are fortunate that the study has been published in a well organised and carefully documented manner and presents a great deal more useful information than is obtainable from the Harvard study publication.

Weight for Height Standards:

The earliest weight for height standard for adults are "standard height-weight tables" by the Life Insurance Companies produced initially in 1912 (Medico Actuarial Mortality Investigations, Association of Life Insurance, Med., Directories, 1959). These tables have been revised by the Metropolitan Life Insurance Company (1959) and form the basis for the most widely used standards of weight for height for adults.

The limitations in the use of these standards have been fully discussed by Seltzer (1965) and Baird (1973) and can be summarized as follows:

1. Insurance tables are based on measurements recorded with shoes and adjustments must often be made.

2. The frame size description into large, medium or small frame is arbitrary.

3. The samples measured are heavily biased in favour of the higher socio-economic groups who would take out life insurance policies.

The Metropolitan Insurance Tables are also based on data collected mainly from adults between 20 and 30 years of age. They present both average weights and "desirable" weight based on the life expectancy of men and women of differing weights for heights. Baird pointed out that the increase in weight after the 3rd decade of life has not been taken into consideration in the preparation of these tables. Baird (1973) and Keys et. al., (1972) have reported that in countries such as the U.K. and U.S.A. the mean weight has shown an increase among adults who are in their fifties.

Kemsley et. al. (1962) published average weight for height for adults in Britain. They took into account the height of the subject and present standard weights for a defined height.

From this brief description of the use of weight for height tables, it should be obvious that huge differences in the distribution of weights could result if adults were grouped solely on the basis of weight for age and sex.

Weight For Height Standards For School Children

The well known weight and height standards are those of Tanner (1958); Tanner and Whitehouse (1959); Tanner et. al. (1966) and Harvard Standards (Stuart and Stevenson, 1959). These tables give the weight and height for age and sex of children but have not been analysed for weight by height.

Scott (1959) also published standards for various anthropometric measurements. His data was collected from 25,000 children, between the ages of 4.5 and 16 years, drawn from schools randomly selected within the County of London. Scott (1959) had analysed weight by height and presented mean weights for 5 cm. height intervals.

Jelliffe (1966) reported a modified version of the original Baldwin-Wood tables for school children which were prepared in 1923 (Baldwin, 1925). These tables were based on records of 129,000 school children between the ages of 6 and 19 years who had at least 5 annual or semi-annual measurements, recorded to the nearest millimeter for height and to the nearest 100 grams for weight. They were constructed as weight for height at different ages for boys and girls respectively. Weight for height for age values were computed as frequency distributions of weight for each height in cm. at each year of age. All children were healthy and were born in America (Baldwin, 1925).

The most up-to-date standards for weight for height for age are the ones reported from the Netherlands and prepared by Van Wieringen (1972). The Dutch standards are based on data collected in 1964-1965, cross sectionally. A very detailed analysis of weight for age, height for age, weight for height have been carried out and reported for both sexes from infancy onwards.

Pre-School Children:

In the WHO Monograph, Jelliffe (1966) also presents weight for height standards for pre-school children which were prepared from Harvard weight for age and height for age data. These will be considered in some detail later.

SECTION II

METHODOLOGY

II. 1. MONTSERRAT SURVEY

In November 1971 the Ministry of Overseas Development made a request to the London School of Hygiene and Tropical Medicine, Department of Human Nutrition for an assessment of the nutritional status of school children in the island of Montserrat, West Indies.

Previous to 1971, the governing body of Montserrat had become concerned about the nutritional status of their school children. Technical advice was requested from international health and nutrition organisations like Pan American Health Organisation (PAHO), Caribbean Food and Nutrition Institute (CFNI) and World Health Organisation (WHO). An expert went to the island and made inquiries about the nutritional conditions and recommended a school meal programme. Following this preliminary work of calculating the cost of a hot meal programme was done by administrators of the island in collaboration with the regional PAHO Nutrition Officer. Financial assistance was requested from the British Government to support this school lunch project which was estimated to cost $ 150.000 E.C. i.e. approximately £ 70.000 per annum.

It was to evaluate the need for this financial assistance that our survey was requested. Our initial terms of reference were "to carry out a study to examine the nutritional needs of school children, to determine the number of cases to whom food supplementation is a real necessity and to recommend how such supplementation might be best effected having regard to the financial implications and in the light of the financial economic circumstances of Montserrat".

In most communities nutritional problems may be expected in pre-school children if there are adverse environmental conditions. We therefore proposed to study the pre-school children as well as school children and to carry out a small scale household survey to find out the basic food consumption pattern. These modifications and proposed plans were discussed. It was arranged that a rapid survey was necessary since there were only two weeks before Christmas holidays when the survey could be carried out on the island.

Since the time allocated by the Ministry was limited to two weeks, the initial plan of the survey had to be carried out in London. Therefore although general information was available it lacked precision and this factor influenced the nature of the subsequent study.

Various reports of health services dating back to 1927 gave some indication of the changes which had taken place in health condition over the years. The report of the Medical and Health Services in 1957 stated that there was malnutrition among the infants under 2 years of age. Low socio-economic level and ignorance were given as contributory factors as well as the wide spread consumption of a "diet high in carbohydrate almost to the exclusion of proteins and vitamins".

A brief report, prepared by Professor Platt after a short visit in 1945 to the island was also found and this supplied early information about the school feeding programmes. He had recommended that a snack meal in the form of milk prepared from skimmed milk powder, and yeast biscuits should be given to school children.

The annual report to the F.A.O. prepared by the Montserrat Health Authorities for the Colonial Office of United Kingdom in 1951 stated that 675 undernourished children in the primary schools were given 3/8 pints of cold milk snack fortified by a food yeast biscuit. According to this information sheet the Infant Welfare Organisation of the Medical Services had distributed 1 pint of cow's milk daily to 100 undernourished children below school age who were selected from various districts throughout the island.

Another brief report by the British Caribbean Advisory Council on Home Economics prepared in 1956 stated that the school feeding programme in Montserrat was in the form of supplementary meal and catered for 80 % of the children. Administration of the scheme was carried out by teachers and senior girls.

The most recent source of information we were able to obtain at that time was the Montserrat Government Report for the years 1965-1966 in which a map of the island was also included.

A. General Background Information

Montserrat is one of the Leeward islands discovered by Columbus in 1493 and lying 27 miles South-West of Antigua and some 40 miles North-West of Guadolupe. It covers an area of 39 square miles and is volcanic in origin.

The climate of the island is tropical and the mean maximum temperature is 86°F with an annual rain fall of about 60 inches. The main rainy season is from September to January.

The island has been a dependent territory for the last 200 years. The execution of Government is through an administrator, an executive council and a legislative council presided by the administrator.

Economy and Agriculture

The currency used is the East Caribbean Dollar exchanging at the rate of \$4.80 (E.C.) to £ 1.00 sterling. In 1970 the Gross Domestic product was estimated as \$11.85 million E.C. or £ 200 per head of population.

Agriculture has been the main occupation of Montserratians but for the last 10 years, the traditional crops of sea island cotton, limes and bananas produced for export have ceased to be a factor influencing the economy of the island, the demand for the once popular sea island cotton has decreased because of man made fabrics.

Natural disasters, such as the hurricane in 1967 have also resulted in a decrease in both the production of domestic food and crops for export. Large, formally productive tracts of land have been given over to real estate development and the islanders have become engaged in real estate and construction work. The newly started tourist industry and the purchase of land by North American and Canadian retirees have changed the economic picture on the island and caused a loss of interest in agriculture.

When we visited Montserrat in 1971, the production of sea-island cotton and lime was on a very small scale and close to extinction. The domestic agricultural produce including vegetables, fruits, live stock products such as meat, eggs and milk were for home consumption only with very little left over for the local market. Agricultural methods are primitive and heavily dependent on man power because the area of land cultivated by most land-owners is small. The unstable hot climate and organisational mishaps in packaging and transportaiton are other factors which affected Montserrat's economy.

The islanders therefore have to depend on imported food which is partly subsidized by the Government. The Government sector is the major source of employment and the contribution of tourist industry is still very minimal. British Aid contributions amount to one fourth of the total recurrent budget.

Population:

According to the 1970 census, the estimated population of the island is 12,300 people. There is one town, the capital, Plymouth. The rest of the island is composed of rural settlements. Emigration to United States of America, United Kingdom and Canada is common. The estimated population for the years 1964, 1965, 1966 and 1970 is given in the table below:

Table II. 1.

The estimated population for the years 1964, 1965 1966 and 1970 in Montserrat

	Years			
	1964	1965	1966	1970
Population	13,729	13,891	14,143	12,300

The difference between 1967 and 1970 is attributed to emigration. The proportion of elderly people and children under 13 years of age is relatively high. 98% of the population is of African ethnic origin. The rest are mostly elderly North American and Canadian retirees who have settled on the island.

General Health Status and Vital Statistics:

The collection of vital statistics has been going on for many years and available information is considered very reliable. The vital statistics for the years 1966, 1967, 1968 and 1969 are given in Table II.2.

Table II.2.

Vital Statistics for the years 1966, 1967, 1968 and 1969 in Montserrat

	Years			
	1966	1967	1968	1969
No. of live births	329	363	322	264
Birth rate/1,000	22.9	25.0	21.9	18.7
Still births	13.0	9.0	10.0	10.0
Death rate/1,000	9.7	10.2	7.8	9.4
Deaths under 1 year	18.0	26.0	14.0	10.0

Table II.3. shows the infant mortality rate over 10 years from 1960 and the figures reflects a considerable improvement in helath with a fall in the infant mortality rate to about 40 per thousand.

Table II.3.

Infant Mortality Rate for the years 1960, 1966, 1968 and 1969 in Montserrat

	Years			
	1960	1966	1968	1969
IMR*	111	54	43	38

* Infant Mortality Rate

Glendon Hospital with 60 beds is situated in the capital Plymouth and provides full medical service. The public health services are carried out by 4 maternal and child clinics and seven health out-posts scattered around the island. At those health centres facilities are provided for the examination and treatment of patients suffering from general medical conditions as well as for pre-natal and infant welfare and preventive measures in the form of immunizations against infectious diseases.

Apart from the hospital and rural welfare clinics there is a sanitary inspection service which includes food hygiene, an infirmary for the poor and elderly, a prison medical service, a port health service, a dental health service and school health services. Table II.4. compares the number of physicians, dentists and graduate nurses in Montserrat with other Caribbean islands as well as United Kingdom.

Table II.4.

The number of physicians, dentists and graduate nurses for every 10,000 of the population of Montserrat, St. Kitts-Nevis-Anguilla, St. Lucia, St. Vincent and the United Kingdom.

Country	Physicians	Dentists	Graduate Nurses
Montserrat	4.3	0.7	22.9
St.Kitts-Nevis-Anguilla	2.6	0.5	8.9
St. Lucia	1.8	0.3	8.8
St. Vincent	1.3	0.4	7.0
United Kingdom	11.7	2.6	35.4

Hospital Admissions

The admission book of the Pediatric Ward provided the necessary information about the causes of hospital admissions to the hospital with special reference to malnutrition and gastro-enteritis. These two conditions are known to be closely linked and often occur together in the same child so the evaluation of either on its own may be misleading. In 1966, 80 children were admitted to the hospital with malnutrition and or gastro-enteritis. There seems to be a considerable fall in the incidence of these conditions over the past 5 years because the number of cases of malnutrition admitted to the hospital has decreased to 21 in 1971. Analysis of records shows that there is a seasonal trend in the incidence with more admissions during the months of September to March. This factor might either be due to seasonal prosperity or changes in climate.

Table II.5.

Admissions and deaths of children with gastro-enteritis and malnutrition, Glendon Hospital.

		Years					
		1966	1967	1968	1969	1970	1971
Gastro-enteritis	Cases	40	26	12	20	9	12
	Deaths	5	10	2	3	0	3
Malnutrition	Cases	40	20	17	7	12	5
	Deaths	4	2	2	0	0	0

There have no important epidemic diseases on the island during those past years. Vitamin A deficiency which was relatively common is reported to be decreasing substantially.

Education

Primary school education is compulsory and free for all children between the ages of 5 and 15 years. There are 13 Government schools, 1 unassisted religious Seventh Day Adventist, 1 grant aided Roman Catholic and 2 privately owned primary schools. The total number of children attending primary schools was approximated as 3,000. The attendance is remarkably good with an average rate of 92% for the last 5 years.

The primary school curriculum leads to the school leaving certificate examination organised from the United Kingdom. Almost 90% of the total population are claimed to read and write.

There is one secondary school where admittance is by an examination. The enrollment of the school is about 250 students per year with 20 staff members many of whom are graduates who reach up to the Advanced General Certificate of Education standard.

Leeward Islands Teacher's Training College provide the teacher training for Montserrat. Various grant aiding organisations provide the financial facilities which allow a considerable number of students to attend this centre.

B. Decisions Taken and Preparations Made Prior To Our Visit To Montserrat

1. School Children:

Choice of Age Groups:

The main purpose of the investigation was to find out the nutritional state of school children. We were obliged to look at the whole group even though we were aware that many of the adolescents were not attending school. This last conclusion was based on the observation of the Government Report of Montserrat, 1965-66 which stated that there were 15 primary schools but only a single secondary school. This school would tend to cater for the more intelligent and probably the more healthy children of parents in a financially advantageous position. If this assumption was correct we would need to rely on finding adolescents in the primary schools if we were to have an appropriate balance of children of all social groups and educational standards. This seemed inherently unlikely in a Caribbean community where in general we understood that adolescent children, particularly the non-academics tend to drift away from school after the age of 13. This was particularly worrying from a nutritional point of view since we considered that the increased nutritional requirements during the adolescent growth period might lead to effects on growth at this time if nutritional deficiencies were a problem on the island. This was one of the factors which led us to insist on an additional survey of pre-school children.

As mentioned in a previous section, primary school education is compulsory and the number of children between the age of 5-15 years enrolled in 15 primary schools in the island is given in Table II.6.

Table II.6.

Numbers enrolled in primary schools and attendance rates for the years 1964, 1965 and 1966*

Years	Enrollment	Average Attendance	Percentage
1964	2,835	2,617	92.0
1965	2,848	2,591	90.9
1966	2,902	2,698	92.9

* From the Montserrat Government Report for the years 1965 and 1966.

Sample Size Estimations:

To decide upon sample size, we needed basic information about the size and distribution of the school children population. The 1970 census figures for Montserrat were not available at the time. Therefore we had to estimate the number of school children between the ages of 5-15 from the figures given in the 1965-66 report.

There had been no previous anthropometric or clinical information collected from the Montserrat population. Professor Platt, during his very short visit to the island could examine only 50 children from various age groups very briefly. Since the mean and the standard deviation for height or weight within this population was not known it was not possible to determine the sample size required statistically if the size was to be based on height or weight differences.

In the case of school children's survey the sample size was largely governed by the time available for the actual survey and the need to have a reasonably sized sample in each age group for comparing Montserratian children with international standards and other Caribbean communities.

The Time Factor:

For the nutritional assessment of school children there were only 5 days available since, within a 2 week period, we wished to survey all children including infants. In the London School of Hygiene and Tropical Medicine some preliminary experimental work by Dr.Colley was helpful in estimating the time which would be needed to measure and examine a child clinically, as shown in Table II. 7.

Table II. 7.

Estimated Timing of Anthropometric Measurements *

Measurement Technique For	Time taken in measuring	Time taken in recording
Weight	20 sec.	10 sec.
Height	10 sec.	10 sec.
Arm mid point measurement	15 sec.	
Arm circumference	10 sec.	10 sec.
Triceps Skinfold T.	15 sec.	10 sec.
Total	70 sec.	40 sec.

* Personal communication with Dr. Colley, 1971.

According to these estimates, it seemed possible to measure and examine one child per minute if a system could be devised to measure each anthropometric parameter separately. If a steady flow of children could be maintained, it would be possible to measure and examine 60 children per hour. Thus the maximum number of children that could be observed within the time available was approximately 1,500 which would be 50% of the total school children population.

Sampling Plan:

We assumed that on the basis of a total population of 15,000 people, we might expect to have 1/4 of the population between the ages of 5 and 15 since this corresponds to the proportion often found in developing countries. We then found out that in 1965 the enrollment was about 3,000 and not 3,750 children as predicted from our assumption.

In a population where the school attendance is 92%, class registers were thought to be a reliable sampling frame. Each child on attending school for the first time had to present his birth certificate; details of the child's name, age and class were therefore would be known (Montserrat Government Report, 1965-66). Assuming that every child on the island of school age is enrolled at school, it seemed unlikely that we would omit even a small group living under very unfavourable conditions.

We were concerned, however, by the possibility that the figure of 92% might be erroneous showing a tendency to over estimate the proportion at school by under estimating the total available childhood population of school age. Thus perhaps there was a 92% attendance of only those who had been registered. Alternatively a 92 % figure might have been a sample figure chosen by an official within the Colonial Ministry, anxious to impress

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We considered several other techniques including household visits to overcome this possibility of non-random sampling, but concluded that the schools offered such an ideal series of assembly points that given the time problem we necessarily were limited to considering only school attenders.

Therefore it was decided to draw a systematic sample of 50 % of the total school children population. Every other child registered on a class register in every class of all the schools on the island was to form our study population. No stratification for sexes and ages seemed to be necessary because when 1,500 children were divided into 2 sexes and 10 age groups there would be over 50 children in each sub-group.

2. Pre-school Children:

Although the Montserrat authorities claimed that school children were suffering from malnutrition and needed supplementary food, it was thought necessary to investigate the nutritional status of pre-school children as well.

Pre-school age, especially the first two years of life is the period when fastest physical growth occurs

(Tanner et. al., 1966). Therefore the nutritional requirements are the highest at this age. If any form of nutritional deficiency were prevalent on the island then the pre-school group might well prove to be the most affected.

The nutritional status of the children in the Caribbean area had been studied by several workers in the previous decade. These studies have concentrated on the larger countries and islands.

Much less attention has been directed to the smaller islands although Ashcroft et. al.(1966) gave figures for the heights and weights of children in Nevis and St. Kitts as part of their anthropological survey of stature in the Caribbean. Recently Gurney et. al. (1972) had reported the nutritional status of young children in Jamaica.

Problem of Sampling:

In order to design a method of investigating the degree of nutritional deficiency among pre-school children we required information of the size of the pre-school population. For the preliminary planning, the summary of the vital statistics reported in the 1965-66 report was thought to be useful.

Table II.8.

Vital Statistics For the Years 1964, 1965 and 1966 *

	Years		
	1964	1965	1966
Total live births	364.0	383.0	344.0
Birth rate per 1000	24.5	27.4	23.7
Infant Mortality Rate /1000	41.2	54.8	54.8
Number of deaths under 1 year	14.9	20.9	20.9
Live children above 1 year	349.0	362.0	323.0

* Figures taken from Government Report 1965-66.

From this table a very rough estimate of the number of pre-school children was made by subtracting the infant mortality rate from the total live births. The average number of live children per year was averaged at 350. The emigration of children with their parents to other countries which undoubtedly occurred to a considerable extent could not be inferred from these figures so we considered at that time that a figure of 1750 might be the maximum number of children available for the study. This figure was subsequently revised on the basis of other information (see later).

Sampling Frame and Sample Size:

Although the Government Report of Montserrat supplied some useful information about the wide-spread health services system and claimed accurate birth and immunization registers, it was decided not to sample the pre-school children population by making use of any kind of registers but to try to include the total population if possible. In cases where accuracy of these registers were not known, the possibility of omitting the most vulnerable had to be guarded against. We were aware of the difficulties involved in assembling a statistically appropriate group which was not a "ready-made" group such as school children or members of the armed forces but the limited time available ruled out house to house visiting. Therefore it was decided to attempt to survey all pre-school children on the island at child welfare clinics and at additional small clinics in the villages. The organisation of the actual survey was left for detailed discussions with the Island health officers. Meanwhile a period of 4 or 5 days was allocated for this part of the survey.

3. Choice of Anthropometric Measurements:

For Montserrat survey, we decided to employ the least time consuming but most informative anthropometric measurements. These measurements were going to be weight, height or length, triceps skinfold thickness and mid arm circumference as recommended by the WHO Monograph (Jelliffe, 1966).

4. Measuring Equipments To Be Used in Montserrat Survey:

Weight:

Two types of weighing scales were chosen

a) Light-Weight Personal Scales, manufactured by Herbert and Sons Ltd. This scale weighs accurately to 50 grams.

b) A light weight baby scale made by Salter and Co. Ltd., which was checked and slightly modified by attaching a new pan at the London School of Hygiene and Tropical Medicine Workshops. This scale weighed accurately to 50 grams also and was used to weigh small babies who were unable to sit or stand.

Height:

Tanner et. al. (1964) have recommended the Holtain (Harpenden) portable stadiometer as the most accurate height measuring device. This equipment is designed for individuals who are over 84 cm. in height, i.e.

for older pre-school children, school children and adults. It consists of an upright (vertical) back plate with a horizontal head piece which operates via miniature ball bearing rollers. There is a digital read out counter and this head block can be easily operated with a slight touch of the finger. This measuring scale is a standardized, manufactured instrument of steel. Although it was very heavy for carrying by one person it was portable. Since it is used extensively in field surveys and is known for its accuracy we considered the cost of the equipment and of its transport to be justified.

b. Montserrat Stick I (Toddler height stick)

This height device was designed by ourselves for the Montserrat study. Although we have taken a Holtain Stadiometer, it was obvious that by itself a Holtain instrument was not going to be sufficient. The children who were not more than 84 cm. in height could not have been measured. For the pre-school group who could stand still but were not tall enough to be measured by the stadiometer, another instrument had to be available. At the time of the survey there was no professionally manufactured height measuring device for this age group so Montserrat Stick I was made at the LSHTM workshops according to our specifications. There was no time to test and then correct the design by trying it out before going to Montserrat.

This stick is consisted of a vertical upright on a horizontal platform. Wooden rulers in metric units were put in the vertical upright. A sliding horizontal wooden plate served as the head piece. The upright was in two pieces and held together with two iron pins. The instrument was completely portable, very light and made of wood only. Its measurement range was from 50 cm. to 150 cm.

Length

Montserrat Stick II (Infant Length stick)

This length measuring device which was made for the Montserrat survey is the simplest of all in design. It was made at LSHTM workshops and resembled a Vernier Caliper. On a 100 cm. long ordinary wooden ruler two metal pieces, both 30 cm. in length, were attached vertically. One of these metal pieces was fixed and used as the foot plate. The other contained a metal spring and slid along the ruler and was used as the head piece. The measurements were made by placing the foot piece beneath the heels of the child, lying flat on a smooth surface and held by the mother. The head piece was then moved towards the head of the child. The length of the child was read from the ruler when the head piece was in the correct position, i.e. when it was touching the head firmly.

Arm Circumference and Skinfold Thickness:

For the arm circumference measurement a steel flexible Miniflex tape manufactured by Rabone and Chesterman was used.

Harpenden calipers (Edwards et. al., 1955) which could read to 0.1 mm. accuracy and exert a constant pressure of 10.3g./mm were used for the triceps skinfold thickness.

5. Survey Forms:

A simple survey form was designed for the survey. Different coloured paper was used to provide easy identification of the sexes; pink for females and blue for males was chosen since we realised that we would need to make some preliminary analysis which had to be rapid. The form was designed for the purposes of our survey and consisted of a seperate sheet of paper for each child. (See figure X,). There was an extra section for the type of clothing since we discovered that we would need to subtract clothing weight and had to distinguish those boys who wore long trousers rather than the usual short trousers.

For pre-school children the clinical examination section was omitted. We were fully aware of the difficulties involved in collecting the children together and were not certain where we could find and examine these children. Since our aim was to measure as many children as possible we decided not to waste time on clinical examination but to refer those children who had obvious or suspected clinical deficiency signs to the doctors or medical authorities on the spot for further examination.

These forms were very simple and they were all prepared and printed before setting off to the Island. Measuring equipment and the forms, as well as the mimeographs of the forms -- to use for more printing if necessary -- were to be flown to Montserrat with us.

As there was no chance of testing the questionnarie, the forms or the preliminary plans before our visit to the island, allowances were made to change decisions if they proved to be inapplicable to the local conditions.

It was decided to ask and obtain maximum cooperation and help from the local Island authorities such as health and school officials. This cooperation was expected because originally it was the Montserrat Government who asked for the supplementary food programme.

II. 2. SURVEY ROUTINE

A. The Alterations Made In The Original Planning:

On our arrival the initial plans for the survey were discussed with the Social Services administrators of Montserrat and precise information about the geographical distribution and the population of the schools was obtained. It became clear that some changes were needed in the original sample size for the school children. There were 17 primary schools and 1 secondary school and total school children population was 1,170 children. These schools were scattered all around the inhabitable parts of the island. Instead of our original plan for taking every other child on every class register in each school, it was decided to include every third child on each register. The reason for this alteration was the time which would be spent in travelling from one school to another since these schools were distributed in relation to the population density in various parts of the island. This decision obviously altered the sample size.

B. Preparatory Work and Training Of The Personnel:

It was explained that for the survey, the assistance of some local personnel was necessary. The chief public health nurse (C.P.H.N.), who was much respected and well known by the people, had accepted to act as the community leader. Our request for 2 people to work as field workers to help with the measurements was accepted, and a large car for transportation together with a driver was provided by the authorities.

With the help of school authorities and the C.P.H.N. a daily schedule for the first week was planned according to the geographical distribution and the population attending the schools. The time which would be spent to travel from one school to another was estimated and it was decided to increase efficiency by visiting schools in the same geographical area on the same day.

The nurse and the clerk who were assigned to help with the survey were trained in taking height and weight measurements. The way to use the equipment and the measurements were taught by myself during the afternoon while contacts were being made with the Chief Minister of the Island by (W.P.T.J.). The purpose of the survey was explained to the Chief Minister and he agreed to make a broadcast over the Montserrat radio to inform the public to ask for their cooperation.

C. The Survey

1. The School Children Survey

The survey of school children was carried out during the first week and can be considered in two phases. Phase I. : The C.P.H.N. visited the schools the day before the scheduled survey day. She distributed the record forms to the class teachers at the school and explained how to select the child to be included in the sample. The class teachers, after choosing every third child on their class registers, filled in the required information about the identity of the child. They were requested to have the children suitably undressed and to have the forms ready before the arrival of the team so that no time would be wasted. The details of the survey were explained to them carefully.

It was emphasized that class teachers should carry out the instructions very carefully so that no complication would arise on the survey day.

Phase II: On the survey day the team arrived at the scheduled school in time and found children ready waiting. The equipment was set up and checked for accuracy and 5 stations of measurement and examination were formed.

Station i : General check of the record form to see that it belonged to the assigned child and to check the information about the sex, age and school class of the subject. Special attention was paid to ensure that the child was correctly undressed and his left arm ready for measurement. Then the child was sent to the next station carrying his own form.

Station ii: Height : The local field worker who was trained measured the height and recorded it to the nearest millimeter below.

Station iii: Weight: The child then moved to the weight station and was weighed. His weight was recorded on the form to the nearest 50 gm., again taking the lower 50 gm. value where an exact weight could not be designated.

Station iv: Arm Circumference and triceps skinfold thickness: These measurements were taken from the left arm of the child by one of us (S.A.) and recorded to the nearest millimeter below.

Station v: Clinical examination: A brief clinical examination was carried out by one of us (W.P.T.J.) at this final station. The forms were then collected and checked after which the child returned to his classroom.

This routine worked very efficiently and we were able to see each in less than a minute. The actual survey performed in the stages given above was repeated at each school.

2. The Pre-school Children Survey:

During the second week of our stay the pre-school children population was surveyed.

Ideally a prevalence survey should be carried out by means of house visiting which offers the advantage of not missing any ill children who would not be brought out of the house (Jelliffe, 1966). Under our circumstances a house-to-house visit was not possible since we had 5 days to cover the entire pre-school population. The major problem was how to collect this population between the ages 0-5 years. The aim was not to sample but to survey the total population.

The discussions with the administrators clarified the following points which were necessary before we could draw our final plan and carry out the survey.

i. Our initial calculations to estimate the pre-school population between the ages 0-5 was still valid in the absence of the 1970 census data.

ii. There was a very efficient network of maternal and child welfare clinics. The birth and clinic records of the children within the coverage of the area of the clinic were kept.

iii. There were 12 clinics and they were scattered all around the island and were well staffed with health personnel.

iv. District Public Health Nurses knew their area well and agreed to help with the survey.

v. There were 3 or 4 kindergartens at various villages for the children between the ages of 3 to 5.

The island was divided into 5 geographical areas. On each day one area was visited. With the help of district public health nurses it was decided to form a mobile survey scheme. It seemed dangerous to depend only on clinics as survey stations so we organized suitable assembly points such as the corner of the village square on the road to Plymouth in front of Mrs. Brown's house or under the well known Mango tree. This was done to enable mothers to bring their children to be examined in a most convenient manner.

A very careful daily schedule was planned with the help of district public health nurse (D.P.H.N.) for the area to be surveyed. This schedule was based on the number of children estimated within that district. Exact positions of survey stations and the time at which the survey team was going to be there were stated. This daily plan, giving the times and places of meeting, was given to the Radio Montserrat to be broadcast in order to inform mothers of the district to attend.

Previously prepared record forms were given to the DPHN of the area to be visited next day. She was asked to fill in the child's identity section of the form according to the clinic records. DPHN was going to be at the scheduled area before the arrival of the team to try to get the children together with their mothers.

It was decided not to carry out a clinical examination (no important sign of deficiency was expected) but to keep clinically-ill children for special examination at the end of each survey session. This was done to save time so that one of us (WPTJ) could concentrate on recruiting as many children as possible.

During the survey a continous search for children was made by one of us driving through the area and visiting households and hailing households located on ridges with a loudspeaker. In many areas the house to house visit was combined with a shuttle service of cars to bring mothers with their children to the measuring team at the designated place.

The measuring team headed by one of us arrived at the stated area in time and set up the equipment. The DPIN was the the first station where she asked the name of the child (in most cases she could recognise them) and gave the filled in form to the mother. If there was no pre-prepared form for the child she asked the name and the age of the child and filled them in an empty form and sent them to the next station. The work flow was similar to the school children survey, with the exception of clinical examination.

In the case of children who were gathered together and brought in without their mothers those recognized by the nurse were included in the survey but those without known birth dates were excluded. In kindergartens the whole routine was, as expected, much easier.

DIAGRAM OF SURVEY ROUTINE

STAGE I

Discussions with administrators

Informing the officials
about initial plans

Obtaining precise information
about geographical distribution
and school population

Recruitment of personnel
a) CPHN
b) 2 field-workers
c) a driver

Transportation
a) a station wagon type car
b) an ordinary car

STAGE II

Preparatory work and training of personnel

Training of field-workers
in taking measurements.

Contacts with Chief Minister
to ensure a brordcast for the
co-operation of the public.

Explaining final survey plan to CPHN
and Education officer and drawing out
schedule of survey for the first week.

STAGE III

The School Children Survey

Phase I

CPHN

visiting each school before the arrival of the survey team and explaining the survey's requirements to the class teachers

Class teachers

a) Selecting children

b) Filling in the forms

c) Preparing children for measurement

Phase II

Arrival of the team

Setting up equipment

Work flow

Station 1

Checking

Station 2

Height

Station 3

Weight

Station 4

Arm C. and Triceps S.T.

Station 5

Clinical Examination

II.3. HOUSEHOLD SURVEYS

It has been an accepted fact that human malnutrition is an ecological problem (Jelliffe, 1966). Where the aim was to assess the nutritional status of a community, it was quite clear that the interacting factors in the community's physical, biological and cultural environment had to be investigated. The availability of various foods and nutrients to persons of different age groups, the general sanitary conditions, climate, soil, irrigation, storage, transport and the socio-economic level of the population as well as customs and traditions had to be investigated in order to have an idea about the nutritional condition of this community.

With our time restricted, it was obvious that a rapid but efficient household survey had to be devised with additional visits if possible to Governmental offices, local markets, cultivation areas, hospitals and other related health and social welfare organisations.

It was decided to draw a small sample of 50 randomly chosen households. Some basic information about the living conditions, food patterns, cooking traditions as well as some socio-economic information could then be collected by means of a questionnaire.

The information available before our visit was insufficient for us to decide on the sampling method for the households to be surveyes. A random method of selection would be employed after discussions with the local authorities.

A. Questionnaires for household survey.

The questionnaire designed for the household survey was a very basic one. Our aim was just to collect general information about some of the ecological factors which might contribute to protein energy malnutrition. The questionnaire was divided into four main sections. The questions were kept very simple and short.

a. General household information

The number of people in the household, their ages, education levels and occupation.

b. General living conditions;

i. Kitchen, cooking facilities, utensils, food storage.

ii. Water supply to the house.

iii. Lavatory conditions;the type, whether they had one or used the bush etc.

c. Food consumption pattern;

i. A day's menu; most of the time what they had the day before.

ii. The source of food and how it was cooked.

iii. Whether they supplied lunch for children who went to school from home or gave money.

d. Questions to give some idea about the general socio-economic level of the households.

i. Whether they owned a piece of land or whether they owned or rented the house they were living in.

ii. Whether they cultivated their land; and if they did, was it for the direct consumption of the members of the household; or whether they owned animals for either of the above purposes.

iii. A direct question about their total household income per month or week.

Although we were mostly interested in the food consumption pattern on the Island, our aim was not necessarily to collect quantitative data. The methods of obtaining quantitative information about food consumption, for example by weighing intakes of individuals or groups of people are very costly, time consuming and difficult (Ritchie, 1950; Marr, 1971).

An analysis of the frequency use of foods in Montserrat on a qualitative basis seemed adequate for our purposes. Even if we had wanted to measure food intakes this would not have been possible in the limited time. We are including information derived from the household surveys in this thesis because it is useful and relevant information which extend our understanding of the classification of "malnutrition" in children.

b. Detailed Planning of Household Surveys in Montserrat:

To decide on the type of sampling method to be employed for the household survey, enquiries were made about a detailed street or area map of the island. Although a census had been taken in 1970 the analysis of this data had not been completed. The actual number of households was not known. A detailed map showing the distribution of households or their locality was not available. Under these circumstances it was decided to employ a random sampling method (Ritchie, 1970).

The sampling frame: This was drawn by using the only available small map of the island, that is the one enclosed with the 1965-66 Government Report. It was estimated that during the first week at least 30 randomly chosen households could be visited. After obtaining further information about population distribution, it was decided to stratify the sample by taking the population density into account.

Plymouth, the capital of the Island, was an urban area with an estimated one-third of the population. It was decided therefore to choose one-third of the household sample from Plymouth and to allocate the rest to the rural areas. The sampling frame was prepared as follows:

i. The map was divided into equal parts by drawing one centimetre square boxes.

ii. Each box was numbered.

iii. With the help of an official who knew the inhabited areas of the Island very thoroughly, two types of regions were excluded from the sampling frame:- a) the mountainous areas and forests where nobody lived, b) the small area on the West side of the Island which was occupied by retired British, Canadians and North Americans. This area was almost completely occupied by very wealthy people who did not lead the same kind of life as Montserratians. In order to minimise any bias in our analysis of economic factors it was decided to exclude this group which was not representative of the Island population.

iv. At this stage, by using a random number table 20 boxes (excluding Plymouth) were chosen randomly from the map. A household was to be chosen from each area, defined within the limits of the box. Plymouth as the urban area was sampled separately.

Although the principles behind the sampling technique of the households were similar, with both the urban and rural areas on the Island, we were forced to use two slightly different methods.

The Town: Ten households were chosen. The CPHN agreed to help with sampling. The dwellings were situated quite densely along the streets and alley-ways and it was considered quite difficult to choose the houses merely by allocating a random number to all the houses in the region. A central place in Plymouth was taken as the starting point. The distance to be travelled was decided from random tables and road junctions and cross roads were used as decision making points. The investigator and the nurse started from the central point and drove in a randomly determined direction until they came to a junction. Random tables were again used to decide which road to take. Odd numbers signified a right turn, and even numbers a left turn. After the full distance allocated for the journey had been covered, the investigator walked along the street, again consulting the random tables in order to choose the number of steps to be taken. If there was another turn but no house, the tables were again consulted to determine the new direction to be taken. This continued until a set of houses was found. The house to be investigated was again chosen randomly from the table.

At this time, this system looked complicated but in practice the series of turns were chosen before the survey by writing down the sequence to be followed having first consulted random tables. Thus instead of stopping the car every few yards it was possible to indicate to the CPHN that the next journey would last 7/10 mile starting in a Northerly direction with each junction being taken according to a set of previously recorded letters. This method was tolerated by the CPHN who knew everybody so well that we felt that considerable bias might arise if we asked her to choose or even be involved with the selection of households for our studies. As a result of using this method we found houses not only along the main streets but hidden behind alley-ways and also across patches of waste land within the town.

The rural areas: For the visits to the rural households the assistance of the DPHN was required. The rural area was composed of small villages scattered around the Island. Geographically it was divided into 4 main sections -- North, East, South and West. The dwellings were usually small which were quite far apart. Most of them were constructed on stilts, with timber and corrugated iron frames, and there was usually a garden.

The boxed area randomly chosen from the map was very carefully examined by the local nurse who knew the area and exact boundaries of the box were established in relation to houses, streams etc. The nurse drove the investigator to this chosen area and was asked to stop the car just beyond the box boundary. Then the investigator chose the direction to walk from the random table and walked 50 yards. If there were no houses around she repeated the procedure. The direction to be taken in order to start the counting of the houses and the choice of the house itself was determined from random tables.

Twenty households were chosen in this fashion and visited during the remaining 4 days of the first week, in the afternoons after the school children survey for the day was completed. We believed that this sampling method, although open to criticism on strict statistical grounds was the best practical solution to our problems at the time. The selected households represented most, if not all, of the diverse standards of living in Montserrat.

During the household visit the questionnaire described above was applied. The respondent was usually the female head of the household. There were no difficulties in establishing a rapport with them and no household refused to cooperate. The reasons for this success can be listed as follows:

1. The Chief Minister had informed them through his broadcast and asked for cooperation. Thus everybody we met had heard of the survey.

2. The whole population was extremely friendly and most of those involved enjoyed taking part in the investigation.

3. The local public health nurse accompanied the investigator up to the doorstep but was asked not to come in by the investigator. This was done in order to avoid any bias in answers given by the householder.

The interview was conducted in such a way that several answers and observations could be used to check the validity of the claims made about the household income, but the reliability of this evidence naturally depended upon the rapport developed during the course of the interview as well as on the bias, both conscious and subconscious, of the householder.

C. Household Survey Of The Poor Households:

During the second week, after the pre-school survey of the day was completed, special visits were made to the households of children who were found to be malnourished during the first week. The same questionnaire was applied. There seemed no reason to draw a special sample for this purpose.

D. Other Investigations:

1. The assessment of food prices: these were made both during household surveys and by visits to

the market in Plymouth and to several shops in the other urban and rural areas.

2. Import arrangements and food storage conditions

3. Poverty and delinquency.

4. Medical services and social welfare system.

5. Other information collected to help with the assessment of the nutritional status of the community.

II. 4. METHODS EMPLOYED TO MINIMIZE ERRORS

However careful the design and execution of an investigation, errors or variations in technique are bound to occur (Walters and Elwood, 1970). In this study the source of errors are grouped as follows:

i. Errors in completing the record form or questionnaire.

ii. Errors in measurement.

iii. Errors in coding.

Errors in completing the record form or questionnaires: the sources of errors in completing the forms are well documented (Walters and Elwood, 1970; Moser and Kalton, 1972). In the context of this study they were mainly due to:

a) Child uncooporation during measurements, this occurred mainly in the pre-school survey.

b) Lack of attention by the field worker. The working conditions were usually unfavourable, noise and a very crowded environment was common.

c) Lack of time: although the survey was designed bearing this problem in mind and organised to limit the difficulties, there were still instances when the field workers had to deal with children within too short a time.

Errors in measurement: this subject will be discussed in detail in connection with two further studies specially designed to find out the instrumental and observer errors.

Errors in coding : every form was coded manually and then the information was transferred to coding sheets which were sent to the London University Computer Centre to be punched on cards. Coding sheets were checked by the investigators by comparing each form with the corresponding coded line on the coding sheet. One person read the codes aloud, the other checked on the sheet. In addition a computer programme was designed for checking the data. All mistakes detected were corrected using the record form before any analysis was attempted.

II.5 . DATA ANALYSIS AND EDITING

The completed record forms were checked on the spot during the survey and errors were corredted if possible.

During the first week in the evenings a crude analysis of heights and weights of children measured that day was made. The record forms were grouped according to age and sex groups. Heights and weights were compared with Boston standards. A child whose height and weight fell below the line 2 standard deviations below the mean value of the standard was considered malnourished. There were two main reasons for this extra effort in making this simple analysis.

a) As mentioned earlier the second part of the household survey was going to be carried out on a very small sample of households where there were severely malnourished children. We felt it would be very useful to investigate the ecological background of a malnourished child while we were on the island.

b) During the survey the officials concerned with the survey were obviously anxious to learn the nutritional status of their school children. To be able to answer some basic questions it was thought necessary to have some immediate impression of their nutritional status.

The crude analysis proved to be helpful in terms of finding a sample of poor homes but fortunately we were not forced to make serious statements about the nutritional status of children based on these findings.

All the forms and household questionnaires were brought back to London for proper analysis. The record forms were checked manually and the ones which had missing data such as the age of the child or any of the anthropometric measurements were discarded. The information on each form was punched on a computer card and data analysis was done at London University Computer Centre.

SECTION III

RESULTS

III. 1. SCHOOL CHILDREN

The results of the measurements of school children will be considered first. The major part of the thesis dealt with the analysis of data from pre-school children. Therefore the section of school children will be dealt with briefly. Later we shall return to a discussion of the usefulness of our survey system once we have analysed the validity of the measurements.

A. Response Rates of School Children

The sampling technique used for the school children's survey has been outlined and discussed in the previous chapter. The non-response rate was estimated from the number of children, chosen from the class registers for inclusion in the survey, who failed to come to the school on the day of the survey. No school children attending school actually refused to be measured; non-respondents were composed of absentees.

Class teachers had filled in the "identity of the child" section of the record card dealing with each child. The forms belonging to the absentees were also collected and a brief investigation into their absence was made by questioning the teachers. None of the teachers could recall any specific illness related to nutritional deficiency and none commented on any chronic illness which might account for their absence; social factors usually appeared to be responsible for their failure to attend school.

Table III.1.

Response Rate: Calculated from the total number of the children on the Island

Total number of school children	Expected sample size: 1/3 of total school population	Total sample size examined	Response rate %
3,186	1,062	1,008	94.9 %

This table gives the total number of children enrolled at schools in Montserrat during the year of 1971. These figures were obtained from the Educational Authorities and they are thought to be reliable. At some schools for example, St. George's, Bethel and Brades the numbers of children shown as registered might be slightly underestimated due to population movements in these more densely populated areas. A detailed breakdown of the number of school children who were expected to be in the sample, based on individual school registers are given in table III.2.

Table III.2.

The breakdown of total school children population for each school: the expected and observed sample response rate in percentages for each school.

Name of School	Total Scl. population	Expected sample	Observed sample	% of the observed
Seventh Day Ad.	72	24	22	92.0
Kinsale	268	89	87	97.7
St. John's	346	115	114	99.0
Plymouth Primary	468	156	154	98.7
Salem	247	82	82	100.0
Cork Hill	229	76	59	77.6
St. George	280	93	93	100.0
Lee's Primary	134	45	45	100.0
Bethel	210	70	70	100.0
Piper Primary	126	42	32	76.1
Long Ground	30	10	8	80.0
Brades	156	52	52	100.0
St. Patrick	143	48	47	97.1
St. Peter's	100	34	34	100.0
Secondary Sch.	240	80	51	63.7
St. Christopher	37	12	11	91.6
St. Augustine	100	34	32	94.1
Total	3186	1062	1008	94.9

As shown in Table III. 1., the over-all response rate for school children surveyed was found to be 95 % which can be regarded as satisfactory.

The two schools which were run with the financial aid of 2 different religious organisations, namely Seventh Day Adventist and St. Augustine schools were mainly interested in educating children of poorer classes. Hence a lower response rate was expected at these schools as absenteeism due to ill health or other factors might be common among very poor children. Despite this possibility, our results show a good response rate of 93 % at these two schools.

Lee's school which had a response rate of 100 % was one of the 3 private fee paying schools; this school was a very popular establishment accepted by the Island community. Piper Primary however had a low response rate of 75.1 % and seemed to cater for the "nouveaux-riche" within this community. The third school, St. Christopher's was a small school established for selected expatriate children who were aiming at high standards of education.

On the other hand, among the Government run schools with 2 exceptions, the response rate was found to be very satisfactory. However at Cork Hill school there were only 77.6 % response rate. The behaviour of the Head master of this school, known for this strictness may have been a factor. Certainly nearly all the children in this school were in tears when surveyed and the school was undoubtedly a very unhappy place.

The unfavourable geographical situation of Long Ground School in the most rural part of the Island might be the cause of its 80 % response rate.

Thus in general the response rate in the island was sufficiently good for us to feel reasonably confident that we could proceed to analyse our results in the knowledge that we had a representative sample and that our conclusions would not be affected by the exclusion of a group of children with unusual problems.

B. The Sample Distribution of School Children

The table III.3. shows the distribution of school children in the different age groups in Montserrat in 1971. The children are classified according to sex and in 10 age groups; the numbers and the percentages in each group are given separately.

In our school children sample, 48.2 % of the children were boys and 51.8 % were girls. No significant difference was observed between the proportions of both sexes in any age group ($P < 0.05$).

Although children start school at 5 years of age, we found 15 children who had been sent to school before the age of 5. When these children are grouped according to their birth dates, none was found below the age of 4 years and 9 months.

Table III.1.

The Distribution of School Children By Age and Sex

Age Group Years	Males		Females		Total
	No.	%	No.	%	No.
4-5	7	70.0	3	30.0	10
5-6	52	50.0	52	50.0	104
6-7	50	47.0	56	52.8	106
7-8	56	48.6	59	51.3	115
8-9	66	54.3	47	45.6	103
9-10	54	51.4	51	48.5	105
10-11	40	48.1	43	51.8	83
11-12	38	42.6	51	57.3	89
12-13	56	54.9	46	45.0	102
13-14	40	45.9	47	54.0	87
14-15	31	45.5	37	54.4	68
15-16	6	22.2	21	77.7	27
16-17	4	44.4	5	55.5	9
Total	490	48.6	518	51.4	1008

$x^2 = 0.38$ DF = 1, not significant at 5% level.

After the age of 13, children tend to leave school. This occurred despite the fact that primary school education is compulsory; children, mainly boys, seemed to leave school to earn their living in their fourteenth year and this was obviously tolerated by the educational authorities.

Emigration to United Kingdom and United States was still common in the years before 1970 and some of the children who are old enough to work might have joined their parents who had already emigrated to these countries.

Secondary school education is neither free nor compulsory. Although there are some grants for bright but disadvantaged children to continue their education, the secondary school in general took students who could pass an entrance examination as well as pay the fees. The sample of children in the secondary school could not therefore be considered representative of the island adolescents.

C. Anthropometric Measurements of School Children

The sample of school children we have surveyed in Montserrat can be considered ethnically homogenous because 98 % of the group was of African origin.

Age Grouping:

Children were grouped in yearly age intervals for example, 4 to 5 years to give a mean height or weight measurement at 4½ years. It was originally planned to use half yearly age intervals in order to narrow the range of measurements for more accurate comparison with the standards available. However, the numbers of children in these half yearly sub-groups would have become too small to allow statistical analysis. Therefore yearly age intervals were used which also made comparison easier with data from other West Indian islands as well as other standards.

a. Comparison of Anthropometric Measurements of Boys and Girls:

Montserrat school children were grouped in 10 age groups for both sexes separately. Tables III.4., III.5., III.6., III.7. and III.8. give the means, medians and the standard deviations of weight, height, arm circumference, muscle circumference and triceps skinfold measurements respectively by age and sex. The number of observations on which these values are based is also given for each age-sex group for each variable.

Weight and height by age and sex

The mean weight difference between the sexes for the ages 5 to 10 years is very small. This difference is not statistically significant (P>0.05), (Figure III.1.). Boys are slightly heavier than girls as expected. This finding is very similar to standards reported for healthy children (Tanner and Whitehouse, 1959; Stuart and Stevenson, 1959; Van Wieringen, 1972). At 10 years girls show a marked

Table III.4.

Means, medians and standard deviations of weight measurements by age and sex.

School Children

Age Groups Inclusive	Boys				Girls			
	n	x	median	SD	n	x	median	SD
5.0-5.11 *	52	17.97	17.60	2.54	52	17.90	17.97	2.07
6.0-6.11	50	19.40	20.10	2.20	56	20.44	20.05	3.81
7.0-7.11	56	22.57	22.65	2.56	59	22.71	22.35	3.70
8.0-8.11	56	25.01	25.70	2.90	47	24.90	24.15	3.26
9.0-9.11	54	28.09	23.00	3.67	51	27.70	27.25	5.66
10.0-10.11	40	29.69	29.00	4.43	43	30.88	30.20	4.76
11.0-11.11	38	32.04	32.80	3.80	51	37.27	36.20	8.79
12.0-12.11	56	37.34	37.35	5.97	46	40.70	39.30	10.22
13.0-13.11	40	39.98	38.65	6.70	47	45.25	44.45	9.51
14.0-14.11	31	45.77	43.15	7.54	37	49.51	47.40	8.22
15.0-15.11	6	53.49	53.30	1.02	21	51.07	50.05	8.15
16.0-16.11	4	51.99		4.41	5	57.60	56.20	7.86

n = number of children, x = mean, SD = standard deviation.

*This signifies the age range where the number after the point refers to months.

Figure III.1

COMPARISON OF WEIGHT OF SCH. BOYS AND SCH. GIRLS IN MONTSERRAT.

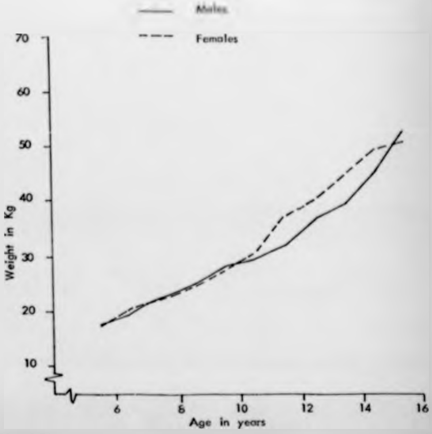


Table III.5.

Means, medians and standard deviations of height measurements by age and sex

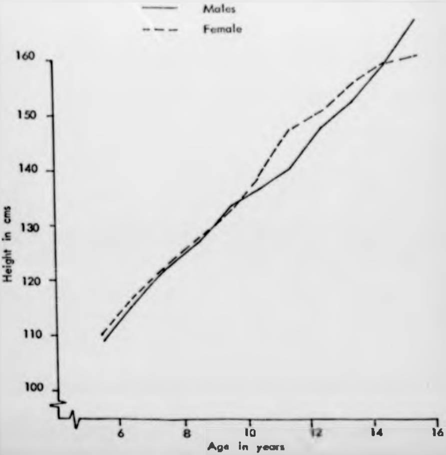
School Children

Age Groups (inclusive)	BOYS				GIRLS			
Y M Y M	n	x	median	SD	n	x	median	SD
5 0-5 11	52	109.2	108.2	5.69	52	110.3	110.0	5.3
6 0-6 11	50	115.7	116.6	6.07	56	116.9	116.0	5.7
7 0-7 11	56	122.1	122.2	5.43	59	122.9	123.2	6.3
8 0-8 11	56	127.5	127.4	6.72	47	128.0	124.7	5.9
9 0-9 11	54	133.7	135,4	6.32	51	133.0	133.5	7.8
1o 0-10 11	40	137.1	137.5	5.66	43	139.4	138.4	6.0
11 0-11 11	38	140.6	140.0	5.48	51	147.7	147.9	6.6
12 0-12 11	56	148.8	148.0	7.58	46	151.2	152.3	7.0
13 0-13 11	40	152.8	153.0	6.91	47	156.5	155.5	7.6
14 0-14 11	31	159.5	158.0	7.54	37	159.8	158.8	5.5
15 0-15 11	6	167.9	169.2	6.91	21	161.2	161.3	4.6
16 0-16 11	4	167.6		4.44	5	171.0	169.5	5.7

N =number of children, x = mean, SD = standard deviation , Y years, M = months

Figure III.2

COMPARISON OF HEIGHT OF SCH. BOYS AND SCH. GIRLS IN MONTSERRAT.



increase in weight and they continue to be heavier than boys until the age of 15. The mean difference in weight of boys and girls is 3.5 kg., ranging between 1.2 kg. and 5.0 kg. for the 5 age groups from 10 to 15 years of age (Table III.4., Figure III.1).

According to Table III.5. and Figure III.2. although the difference in mean height for both sexes is small and is not statistically significant between the ages 5 and 8 years, boys are slightly shorter than girls. After the age of 10 the girls' height and weight show evidence of the adolescent spurt. The average difference in the mean heights between sexes is found to be 2 cm. At 11 ½ years girls are 6 cm. taller than boys.

Tanner (1962) has emphasized that males mature more slowly than females and that females are more advanced in skeleton ossification even before birth. The differences observed might then reflect the time difference in the beginning of the adolescent spurt, girls maturing earlier than boys. On the other hand, although boys mature later than girls they tend to be physically larger and it was suggested that in the male the whole body has a longer period of growth resulting in a greater size.

Sex differences in relation to malnutrition have been established (Tanner, 1962). Girls are usually less effected by adverse environmental factors than boys. Greulich (1957) had shown that although the group of children he surveyed was retarded in height and weight, girls were less retarded than boys. This may be true for Montserrat children, under their adverse environmental conditions: girls seem to grow better than boys.

Arm Circumference, Muscle Circumference and Triceps Skinfold Thickness Measurements by Age and Sex:

Tables III.6., III.7. and III.8. give the mean, median and the standard deviations of arm circumference, muscle circumference and triceps skinfold measurements for both sexes aged 5 to 15 years. Figure III.3. illustrates the trend in arm circumference for age curves for both sexes which is very similar to weight for age curves. The relationship between arm circumference for age and weight for age has been well documented (Gurney, 1969; Jelliffe, 1969; Robinow and Jelliffe, 1969 Rutishauser, 1969).

The differences in triceps skinfold measurements for both sexes are significantly different at all ages ($P<0.01$). (Figure III.4.). Girls tend to have fatter arm circumferences than boys. After puberty this difference becomes very marked. On the other hand the muscle circumference for boys were greater than girls (Figure III.5. Table III.8.) It is obvious that while girls put on fat the amount of muscle laid down by boys is significantly more than girls. Tanner (1962) reports that from early childhood, boys have slightly more bone and muscle and probably also a slightly higher growth rate in both these tissues. The sex differences remain small until the age of 7 years. At adolescence, however, in the male there is a large spurt in both muscle and bone growth with a loss of fat. In the female there is very little spurt in bone growth but a large gain in fat.

We can not demonstrate the growth rates for Montserrat children because the data is cross sectional. Although Montserrat boys do not show superiority in terms of height attained by age over girls (Figure III.2.), they develop more muscle but less fat than girls during their development (Figures III.4., and III.5).

Table III.6.

Means, medians and standard deviations of arm circumference measurements by age and sex

School Children

Age Groups inclusive	BOYS				GIRLS			
Y M Y M	n	x	median	SD	n	x	median	SD
5 0-5 11	52	16.52	16.50	1.25	52	16.38	16.20	1.08
6 0-6 11	50	15.44	16.30	1.14	56	17.04	16.80	2.13
7 0-7 11	56	17.50	17.60	0.98	59	17.63	17.30	1.99
8 0-8 11	56	18.17	18.10	1.29	47	18.03	18.10	1.27
9 0-9 11	54	18.89	18.90	1.40	51	18.64	18.30	2.03
10 0-10 11	40	19.23	19.00	1.67	43	19.09	18.70	1.78
11 0-11 11	38	19.32	19.30	1.59	51	20.60	20.30	2.21
12 0-12 11	56	21.02	21.00	1.69	46	21.35	20.70	2.64
13 0-13 11	40	21.15	21.00	1.98	47	22.02	21.00	3.20
14 0-14 11	31	22.55	22.70	2.25	37	23.13	23.40	2.58
15 0-15 11	6	24.37	24.30	2.45	21	23.88	24.50	2.38
16 0-16 11	4	24.32		1.20	5	24.04	23.10	1.50

n = number of children, x = mean, SD = standard deviation, Y = years, M = months

Table III.7.

Means, medians and standard deviations of Triceps Skinfold Thickness measurements by age and sex

School Children

Age Groups inclusive	BOYS				GIRLS			
Y M Y M	n	x	median	SD	n	x	median	SD
5 0-5 11	52	6.04	6.10	1.09	52	6.82	6.80	1.43
6 0-6 11	50	5.31	5.10	1.00	56	6.78	6.40	2.10
7 0-7 11	56	5.58	5.60	1.12	59	6.89	6.40	2.12
8 0-8 11	56	5.51	5.10	1.44	47	7.35	7.00	1.76
9 0-9 11	54	5.82	5.60	1.68	51	7.60	6.80	3.27
10 0-10 11	40	6.12	5.60	2.38	43	7.68	7.10	1.96
11 0-11 11	38	5.68	5.60	1.46	51	8.78	7.60	3.74
12 0-12 11	56	6.42	6.30	1.93	46	9.73	8.30	4.40
13 0-13 11	40	6.24	6.00	1.88	47	10.26	8.60	5.08
14 0-14 11	31	6.62	6.40	2.13	37	10.73	10.10	3.60
15 0-15 11	6	5.98	5.70	1.63	21	12.00	11.30	3.83
16 0-16 11	4	5.65		0.92	5	11.20	9.40	3.75

n = number of children, x = mean, SD = standard deviation, Y = years, M = months

Table III.8.

Means, medians and standard deviations of Muscle Circumference Measurements by Age and Sex

School Children

Age Groups inclusive	BOYS				GIRLS			
Y M Y M	n	x	median	SD	n	x	median	SD
5 0-5 11	52	14.62	14.50	1.14	52	14.24	14.28	0.92
6 0-6 11	50	14.77	14.81	1.07	55	14.90	14.70	1.72
7 0-7 11	56	15.75	15.77	0.90	59	15.46	15.30	1.55
8 0-8 11	56	16.44	16.55	1.18	47	15.72	15.53	1.03
9 0-9 11	54	17.06	17.05	1.27	51	16.25	15.18	1.40
10 0-10 11	40	17.31	17.18	1.22	43	16.67	16.31	1.55
11 0-11 11	38	17.53	17.68	1.36	51	17.80	17.63	1.48
12 0-12 11	56	19.00	18.86	1.60	46	18.29	17.99	1.68
13 0-13 11	40	19.19	19.14	1.76	47	18.80	18.62	1.90
14 0 14 11	31	20.47	20.61	2.00	37	19.76	19.80	2.10
15 0-15 11	6	22.49	23.51	2.67	21	20.11	20.69	1.50
16 0-16 11	4	22.55		1.06	5	20.52	20.14	1.73

n = number of children, x= mean, SD = standard deviation, Y = Years, M= months.

Figure III.3

A COMPARISON OF ARM CIRCUMFERENCE MEASUREMENT OF MONTSERRAT SCHOOL BOYS AND GIRLS.

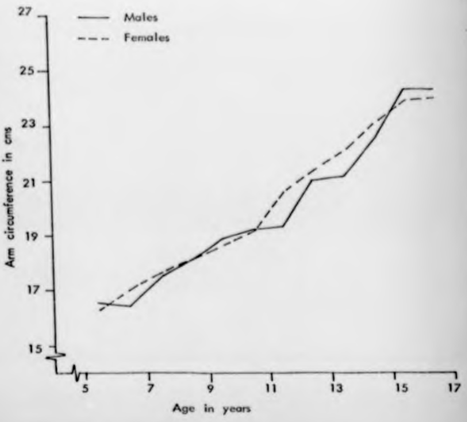


Figure III.4

COMPARISON OF TRICEPS SKINFOLD MEASUREMENT OF MONTSERRAT SCH. BOYS AND SCH. GIRLS.

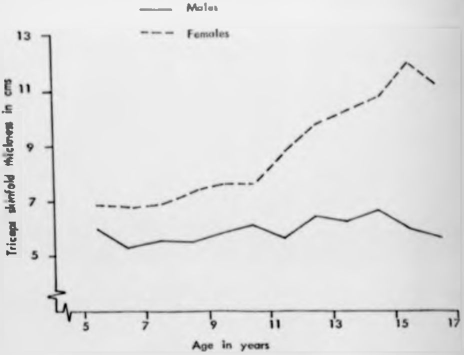


Figure XII.5.

A COMPARISON OF MUSCLE CIRCUMFERENCE MEASUREMENT OF MONTSERRAT SCHOOL BOYS AND GIRLS.

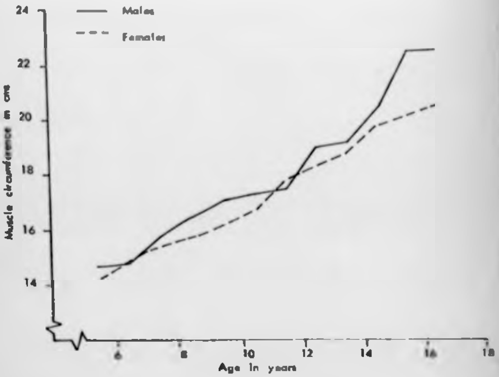
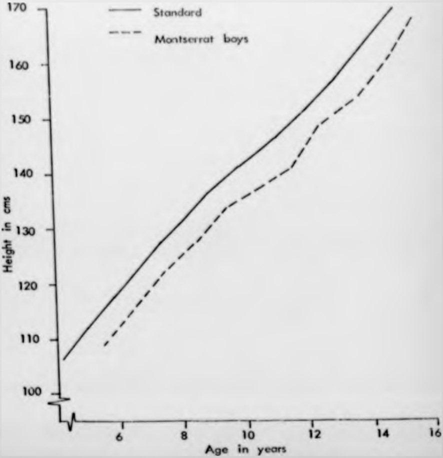


Figure III. 6.

COMPARISON OF THE HEIGHT OF MONTSERRAT SCH. BOYS WITH HARVARD STANDARDS.



B. Comparison of the Anthropometric Measurements of School children With the Standards:

The mean weights and heights of Montserrat school children were compared with the Harvard standards. Boys and girls have to be assessed separately since they show different rates of growth, particularly during the adolescent phase of development.

Arm measurements i.e. arm and muscle circumference and triceps skinfold thickness were compared with the reference standards given in the WHO Monograph (Jelliffe, 1966).

Figures III.6., III.7., III.8. and III.9. present the mean heights and weights of boys and girls respectively at each age together with the Harvard standards. The figures have been plotted at the mid points of yearly age intervals.

The 50 th percentile Harvard standards are chosen as the reference for comparison because evidence is accumulating (Ashcroft and Lovell, 1964a, Scott et. al., 1950) that the Negro and Caucasian races have about the same growth potential given the same diet, but whether or not it is the normal or ideal standard for African origin children, the Harvard standard curve is a convenient standard for comparison.

School boys in Montserrat have average weights and heights which are below the Harvard standards, being approximately 10 % below the standard. Above the age of 12 the Montserrat boys' height and weight appear to improve.

Montserratian school girls are also on average underweight and a little shorter than Harvard standard. Eventually when aged 15, the girls have attained the standard height and would seem better nourished. Since girls mature earlier than boys their final height is achieved at an earlier age. The boys in Montserrat probably have a delay in puberty of nutritional origin, and take longer to attain their full height.

Figures III.10., III.11., III.12., III.13., III.14. and III.15. show that both boys and girls have smaller arm circumferences than the standard; the children are thin as well as small. Measurements of the thickness of the skin and underlying fat layer show that the school children in Montserrat in general are likely to have very low reserves of energy. In girls, the average thickness of the skinfold rose rapidly between the ages of 13 and 15. Some girls at these ages were obese, and their measurements raised the average, concealing the low values of many thinner girls.

The muscle circumference measurements of Montserrat boys were along and above the standard for the children between the ages of 5 and 13. Girls also have a very similar pattern. The measurements of older children were below the standard.

Figure III, 7.

A COMPARISON OF HEIGHT OF MONTSERRAT SCHOOL GIRLS WITH BOSTON STANDARDS.

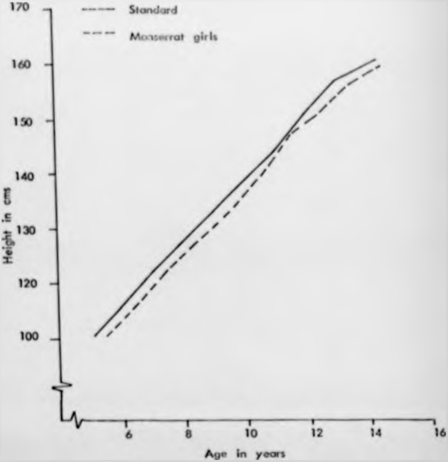


Figure III,8.

A COMPARISON OF WEIGHT OF MONTSERRAT SCHOOL BOYS WITH BOSTON STANDARD.

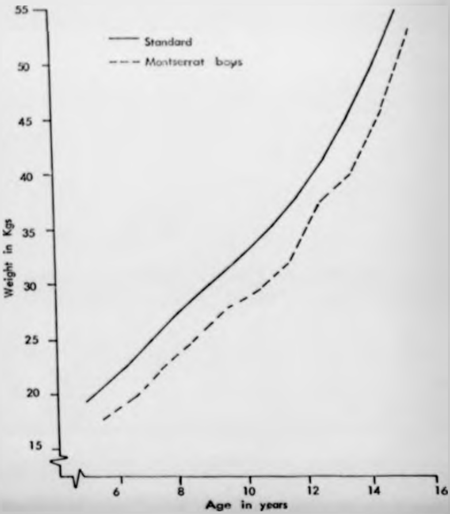


Figure III.9.

A COMPARISON OF WEIGHT OF MONTSERRAT SCHOOL GIRLS WITH BOSTON STANDARD.

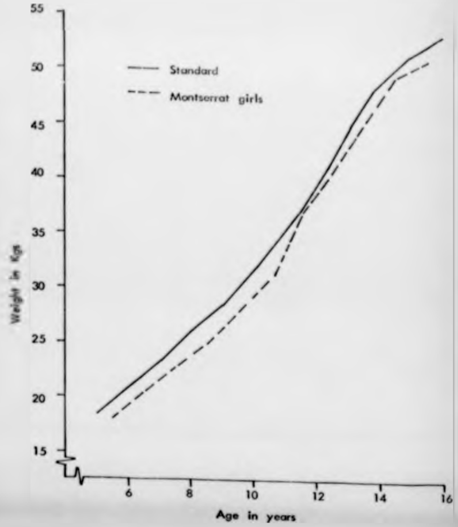


Figure III.30.

COMPARISON OF ARM CIRCUMFERENCE MEASUREMENT OF MONTSERRAT SCH. GIRLS WITH THE STANDARD.

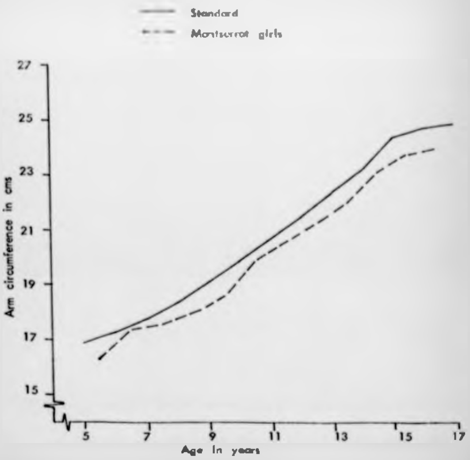


Figure III.11.

COMPARISON OF ARM CIRCUMFERENCE MEASUREMENT OF MONTSERRAT SCH. BOYS WITH THE STANDARD.

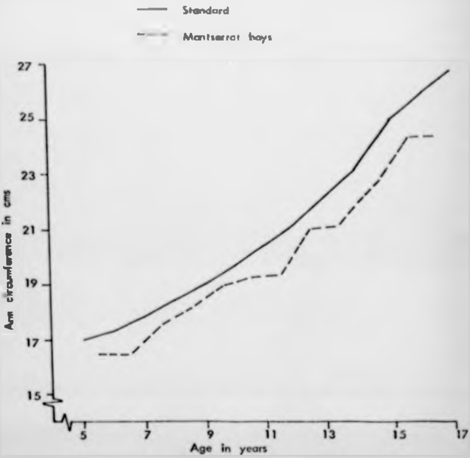


Figure III.12.

COMPARISON OF TRICEPS SKINFOLD MEASUREMENT OF MONTSERRAT SCH. BOYS WITH THE STANDARD.

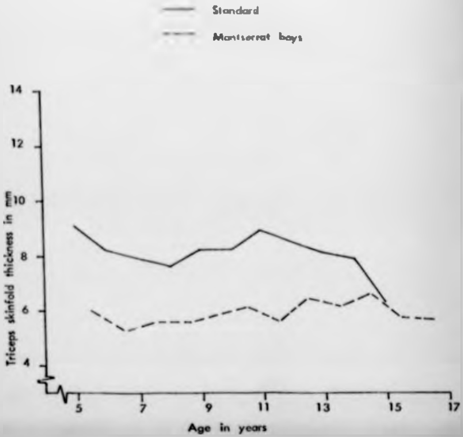


Figure III. 15.

COMPARISON OF TRICEPS SKINFOLD MEASUREMENT OF MONTSERRAT SCH. GIRLS WITH THE STANDARD.

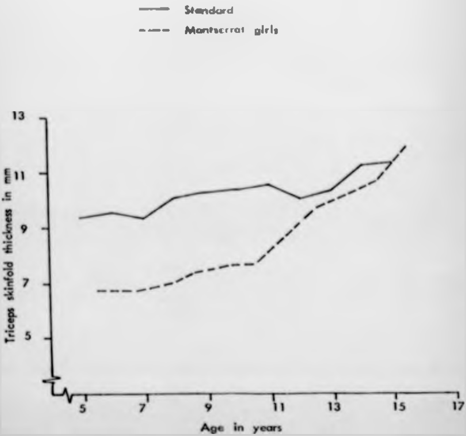


Figure III.14

COMPARISON OF MUSCLE CIRCUMFERENCE MEASUREMENTS OF MONTSERRAT SCH. BOYS WITH THE STANDARD.

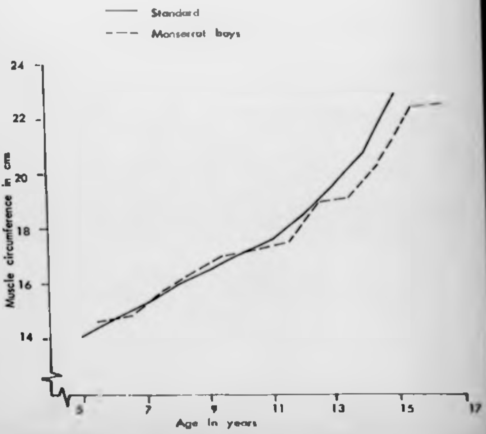
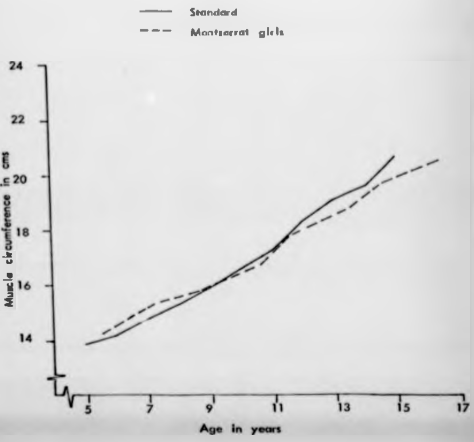


Figure III, 15.

COMPARISON OF MUSCLE CIRCUMFERENCE MEASUREMENTS OF MONTSERRAT SCH. GIRLS WITH THE STANDARD.



III. 2. PRE-SCHOOL CHILDREN

A. Response Rates:

In the absence of accurate data we had to estimate the number of children on the Island as explained in the Methodology Section. We found different information on birth rates when we arrived in Montserrat.

An attempt was made to include all children between the ages of 0 months and 5 years. According to our rough estimates there might be 1,600 children under 5 years of age to be surveyed within the allocated time period of 4 days. Table III.9. gives the figures used for the estimation of total pre-school children population.

There were about 60 children between the ages of 4 ½ and 5 ½ years who had started school. During our survey we examined 20 children from this age group at schools and excluded 40 children by the sampling method used for the school children survey.

The calculations for estimating the response rate were based on the assumption that:

$$\begin{bmatrix}\text{Total expected}\\ \text{number of children}\end{bmatrix} - \begin{bmatrix}\text{Observed}\\ \text{number of children}\end{bmatrix} = \begin{bmatrix}\text{Number of}\\ \text{non respondents}\end{bmatrix}$$

If we consider the total number of children observed as 1,024 + 60 (observed number + children who had been missed because they were at school) this will give us a

Table III.9

Estimation of Pre-school children Population of Montserrat

Years of birth	Ages	Number of Live Births	Infant Mortality Rate per 1000	No. of Deaths under 1 year	Expected No. of children	Observed No. of children
1971 - 1970	1	330 (E)*	40	13	317	194
1970 - 1969	2	330 (E)*	40	13	317	221
1969 - 1968	3	330 (E)*	40	13	317	203
1968 - 1967	4	322 (C)*	43	14	308	261
1967 - 1966	5	363 (C)*	54	20	343	256
		1675		73	1602	1135

* (E) = Estimated figure from the Montserrat Government Report for the years 1965 and 1966

* (C) = Corrected figures from Government Health Report and Vital Statistics.

minimum response rate of 75.1 % .

However, we believe that we measured a higher percentage of children than that calculated. When clinic record cards were inspected, there appeared to be well over a 90 % attendance in all but two areas of the Island. These record cards were based not only on the child's attendance at a clinic but on the compulsory legal registration of birth. We were obviously concerned that children attending clinics in these two low attendance areas with a poor response might prove to be a self selecting group with anthropometric indices different from the norm. In fact, children attending clinics during the survey in these two areas were subsequently shown to have similar anthropometric values to the children from other areas where the response rate was good despite the wide-spread distribution of poverty and adverse social conditions. These areas were not excluded from analysis since preferential selection of well or poorly nourished children did not appear to have occurred.

Of the examined pre-school children there were 111 who either had incomplete record cards or whose mother was not immidiately available to give the appropriate information; these children had to be excluded from the analysis so that the final sample size was 1,024 children.

D. Sample Distribution By Age And Sex:

Table III. 10. gives the values for the pre-school children sample divided into groups by age and sex. There was a fairly even distribution of cases over the whole range of ages studied in both sexes.

Table III. 10.

Distribution of Sample by Age and Sex In Yearly Age Groups

Age Groups in months	Males		Females		Total	
	n	%	n	%	n	%
0-11	97	9.4	87	8.5	184	18.1
12-23	99	9.7	107	10.4	206	20.1
24-35	85	8.3	93	9.1	178	17.4
36-47	113	11.0	118	11.8	231	22.4
48-60	109	10.6	116	11.3	225	22.0
Total	503	49.0	521	50.8	1024	100.0

For greater precision and ease of comparison with other data, the children were grouped in narrower age ranges. Growth rate in terms of weight is maximal just before birth when most of the subcutenous adipose tissue is added. By birth, length and weight are proportional and although the first 2 years are considered as the most rapid growth period of post natal life the growth velocity slows down gradually with increasing age until puberty (Tanner, 1962; Cheek, 1968).

In our group the children under one year of age are divided into 3 monthly age intervals and the numbers in each age group vary between 34 to 52. Although these numbers seem to be small, it was thought to be necessary to have relatively narrow age intervals in a period of such rapid growth in order to show any real deviations from the values of helathy children represented by 'standards'. For children over the age of 1 year a division of 6 monthly intervals was considered appropriate.

Sex Grouping:

The pre-school children were grouped according to sex within the described age intervals. This division resulted in even smaller numbers of children in each age and sex interval. This reduction in numbers was inevitable since we wished to compare the anthropometric measurements of boys with girls. Later we combined the sexes to make our data comparable with other data from other Caribbean islands as well as with standards given for both sexes combined (Jelliffe, 1966).

A close observation of the distribution of Montserrat pre-school children by sex and age revealed that there is a relatively even distribution of boys and girls in each month interval up to 5 years. The number of girls are slightly more than boys but the difference is about 2 %. There were no significant differences between the numbers of children in both sexes at any age ($P > 0.05$).

C. Analysis Of The Anthropometric Measurements Of Montserrat Pre-school Children: Sex differences, Distributions and Comparison of mean values with Standards.

The following anthropometric data and the interpretations used relate to a cross sectional study. Often however, for simplicity or expression, the data will be considered as though it related to a longitudinal study. Thus secular changes in growth pattern will be ignored as a complication. The limitations of this approach will be considered later.

In this section, the characteristics of the distributions of these anthropometric measurements and the differences between the sexes will be analysed and the data will be compared graphically with Harvard standards .

Differences between sexes were examined because there have been reports suggesting that boys and girls have different growth patterns from birth. According to Fomon (1968) infant males are somewhat larger than infant females and he believes that this difference is of gonadal origin. He also reports a greater rate of gain in weight and length in boys during infancy. Data collected from twins also showed that the male twin is greater in size than the female co-twin (Karn, 1956). Cheek (1972) also emphasized the differences in body composition of boys and girls in his paper which discusses the mathematical equations derived to predict total body water from height and weight. A close observation of the standards for example, the Harvard (Stuart and Stevenson, 1959) and Dutch (Van Wieringen, 1972) values demonstrate these small differences between the sexes.

Tables summarizing the anthropometric data as the mean with standard deviations and also as five percentile groups were prepared. In these tables the median is the 50th percentile for the whole group produced by combining the sexes at specific age intervals. (Tables III.1., III.2., III.3., III.4. and III.[illegible].)

Weight For Age:

In Figure III. 16. the line connecting the mean values at each age interval represents a "distance curve" for weight for age. The distribution of weights within a population is not strictly Gaussian. This can be observed from the relative positions of the mean and median. At various ages, for example at 7, 10 and 26th months the mean and the median values do not correspond to each other and the differences between the two measures of location raise the possibility that this discrepancy is due to the combination of data from both sexes. However a close observation of the distributions of weights in each sex separately showed differences between

Table III.[illegible]

Means, Medians, Standard Deviations and Percentile Distributions of Height Measurements of Montserrat Pre-school Children.

(Sexes Combined)

Age Group in Months	n	Height in cms.			Percentiles				
		$\bar{x}$	median	SD	90th	70th	50th	30th	10th
0-2	34	54.61	54.00	6.39	58.20	56.30	54.00	51.70	49.20
3-5	52	60.57	60.80	3.34	64.10	63.00	60.80	58.80	56.80
6-8	51	66.25	66.30	3.26	70.10	68.10	66.30	65.00	62.90
9-11	47	70.60	71.10	3.22	75.00	72.90	71.10	67.90	67.00
12-17	117	74.19	74.00	4.69	78.20	76.60	74.00	71.00	69.00
18-23	89	79.29	79.30	4.29	84.10	82.20	79.30	76.60	74.10
24-29	90	85.13	85.20	5.36	91.60	88.20	85.20	81.40	79.40
30-35	88	91.52	91.71	4.62	97.70	94.50	91.70	88.40	85.30
36-41	105	95.46	95.30	4.38	101.10	98.30	95.30	92.50	90.30
42-47	126	98.47	99.00	4.32	103.30	101.30	99.00	95.40	93.00
48-53	112	102.10	102.10	5.20	107.70	105.40	102.10	99.40	96.50
54-60	113	106.30	106.70	4.91	112.20	109.20	106.70	103.40	101.00

Table III.7

Means, Medians, Standard Deviations and Percentile Distributions of Weight for Age of Montserrat Pre-School Children.

(Sexes Combined)

Age Group Months	n	Weight in Kgm.			Percentiles				
		X	median	SD	90th	70th	50th	30th	10th
0-2	34	4.80	4.85	1.38	5.65	5.25	4.85	4.10	3.22
3-5	52	6.46	6.50	1.09	8.05	7.25	6.50	5.80	4.75
6-8	51	7.76	8.00	1.27	9.15	8.80	8.00	6.75	6.20
9-11	47	8.96	8.60	1.36	10.85	9.80	8.60	8.00	7.50
12-17	117	9.63	9.60	1.38	11.40	10.35	9.60	8.75	7.75
18-23	89	10.57	10.55	1.37	12.40	11.60	10.55	9.70	8.75
24-29	90	12.12	11.90	1.70	14.40	13.00	11.90	11.05	10.20
30-35	88	13.10	13.12	1.73	15.60	14.20	13.10	11.90	10.80
36-41	105	14.14	13.95	1.70	16.10	15.20	13.95	13.05	12.10
42-47	126	15.00	15.30	1.87	16.90	15.85	15.30	13.95	13.00
48-53	112	15.79	15.55	1.87	18.20	17.20	15.55	14.60	13.65
54-60	113	17.13	17.10	2.11	19.60	19.60	18.40	15.75	14.60

Table III.13.

Means, Medians, Standard Deviations and Percentile Distributions of Arm Circumference Measurements of Montserrat Pre-School Children.

(Sexes Combined)

Age Group in Months	n	Arm Circumference in CMS.			Percentiles				
		x	median	SD	90th	70th	50th	30th	10th
0-2	34	12.00	11.75	1.47	13.10	12.70	12.00	11.20	9.50
3-5	52	13.50	13.47	1.17	14.80	14.10	13.50	12.50	12.10
6-8	51	14.00	14.02	1.36	15.90	14.90	14.00	13.10	12.20
9-11	47	14.30	14.71	1.32	16.50	15.60	14.30	13.50	13.10
12-17	117	14.60	14.71	1.16	16.40	15.30	14.60	14.00	13.30
18-23	89	14.60	14.61	1.16	16.20	15.60	14.60	14.00	13.10
24-29	90	15.00	15.05	1.13	16.40	15.70	15.00	14.30	13.90
30-35	88	15.30	15.34	1.13	16.90	16.00	15.30	14.50	14.00
36-41	105	15.30	15.28	1.49	16.80	16.00	15.30	14.60	13.90
42-47	126	15.50	15.65	1.46	17.00	16.10	15.50	14.70	14.40
54-60	113	16.20	16.25	1.20	17.80	17.00	16.20	15.30	14.90

Table III.4

Means, Medians, Standard Deviations and Percentile Distributions of Triceps Skinfold Thickness Measurements of Montserrat Pre-School Children.

(Sexes Combined)

Age Group in Months	n	Triceps Skinfold Thickness in mm.			Percentiles				
		$\bar{x}$	median	SD	90th	70th	50th	30th	10th
0–2	34	7.66	7.60	1.77	9.60	8.60	7.60	6.90	5.70
3–5	52	9.38	9.10	2.02	12.10	10.60	9.10	8.10	7.20
6–8	51	8.63	8.30	1.60	10.40	9.90	8.30	7.40	6.90
9–11	47	7.96	7.40	1.87	10.80	9.40	7.40	6.60	6.20
12–17	117	7.70	7.40	1.40	9.80	8.60	7.40	6.80	5.96
18–23	89	7.57	7.40	1.44	9.60	8.30	7.40	6.60	5.80
24–29	90	7.63	7.70	1.47	9.40	8.60	7.40	6.40	5.70
30–35	88	7.89	7.50	1.70	10.30	9.20	7.50	6.80	6.10
36–41	105	7.14	7.10	1.35	8.90	7.80	7.00	6.20	5.60
42–47	126	7.36	7.10	1.74	9.50	8.20	7.10	6.30	5.50
48–53	112	7.06	7.00	1.48	8.80	7.90	7.00	6.10	5.40
54–60	113	6.92	6.80	1.68	8.80	8.00	6.80	5.80	5.20

Table III.15

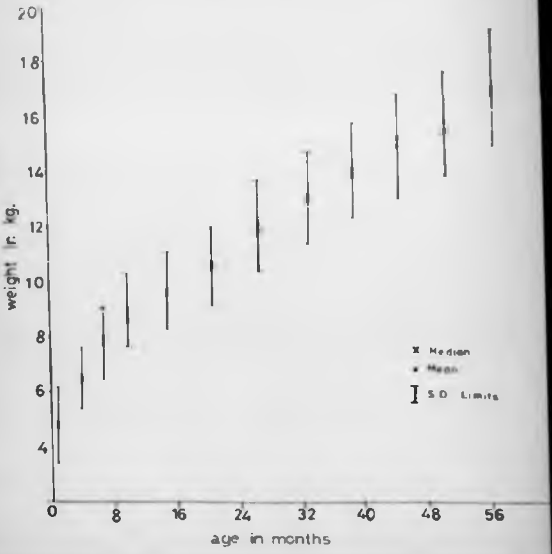
Means, Medians, Standard Deviations and Percentile Distributions of Muscle Circumference Measurements of Montserrat Pre-School Children.

(Sexes Combined)

Age Group in Months	n	Muscle Circumference in cms.			Percentiles				
		x	median	SD	90th	70th	50th	30th	10th
0-2	34	9.34	9.50	1.21	10.49	9.80	9.50	8.78	7.49
3-5	52	10.53	10.64	0.[illegible]8	11.50	11.27	10.64	9.70	9.22
6-8	51	11.31	11.17	1.07	12.76	11.92	11.17	10.62	9.80
12-17	117	12.29	12.20	0.99	13.61	12.95	12.20	11.57	10.99
18-23	89	12.23	12.28	1.02	13.62	13.02	12.28	11.61	10.96
24-29	90	12.65	12.60	1.00	14.04	13.24	12.60	12.01	11.49
30-35	88	12.86	12.88	0.90	14.11	13.39	12.88	12.09	11.62
36-41	105	13.04	13.21	1.42	14.44	13.77	13.21	12.37	11.83
42-47	126	13.34	13.23	1.05	14.59	14.13	13.23	12.58	12.17
48-53	112	13.66	13.74	1.0[illegible]	14.92	14.37	13.24	12.89	12.35
54-60	113	14.07	14.10	1.04	15.41	14.76	14.10	13.22	12.71

Figure III.16.

WEIGHT DISTRIBUTION OF MONTSERRAT CHILDREN, SEXES COMBINED, MEDIAN MEAN AND S.D. OF THE MEAN.



the mean and the median. Therefore the process of combining the data cannot be considered responsible.

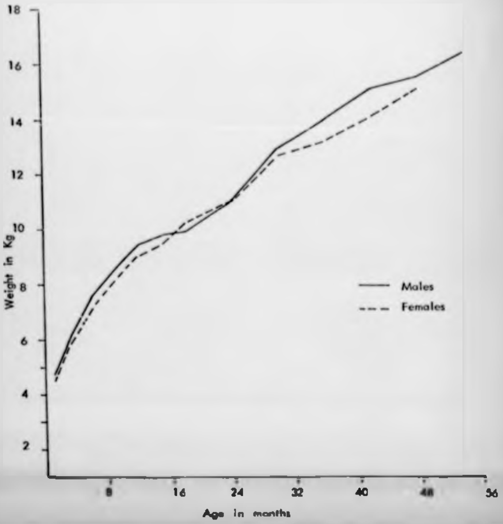
During the first six months weight gain is very rapid and the mean and median values were found to be very similar. The standard deviations of the mean weight, increase with age showing the natural spread of weight due to individual variations in growth. In our series the numbers of children in each group, especially in the first 3 months, are small and the sample size might contribute to the large standard deviations found in some age groups. The general trend, however, is to have a greater distribution as the children become older.

Figure III.17 illustrates the weight for age curves for boys and girls separately. Boys are heavier than girls up to the age of 16 months but the differences at various ages were not found to be statistically significant ($P > .05$). Between 17 and 24 months a change in this pattern occurred with the boys' weights faltering below those of the girls. At 30 months the weight curves for boys and girls were very close to each other but subsequently the boys caught up with girls and were heavier than girls. The differences in weight attained by boys and girls at 3 and 3.5 years were found to be statistically significant ($P < .001$).

Figures III.18&19 give the graphical comparison of the median weights of Montserrat pre-school children with the standards. The birth weights of Montserrat children could not be obtained during the survey but the median

Figure III. 17.

COMPARISON OF WEIGHTS OF MONTSERRAT PRE - SCH. BOYS WITH PRE - SCH. GIRLS.



COMPARISON OF WEIGHTS OF MONTSERRAT PRE - SCH. BOYS WITH THE HARVARD STANDARD.

Figure III. 18.

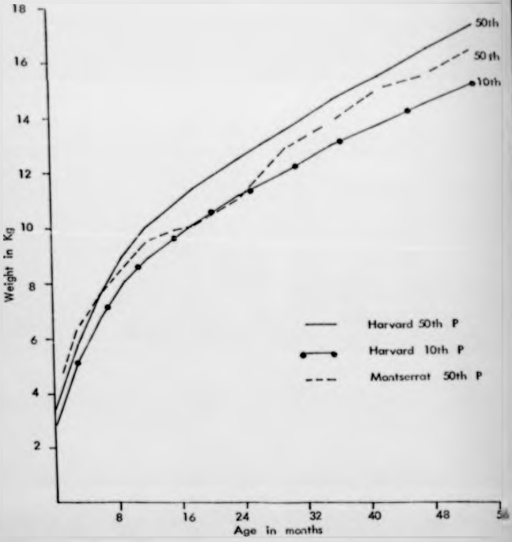
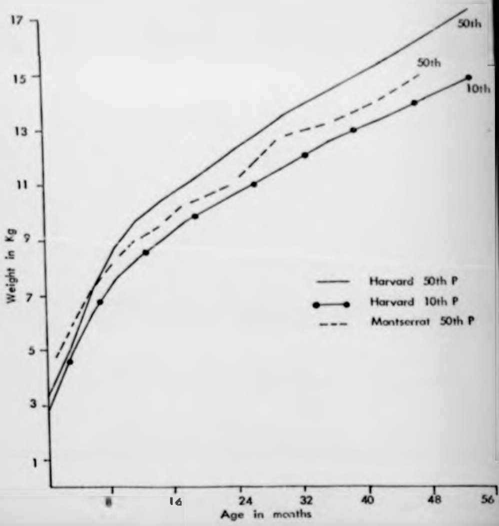


Figure III. 19.

COMPARISON OF WEIGHTS OF MONTSERRAT PRE - SCH. GIRLS WITH THE HARVARD STANDARD.



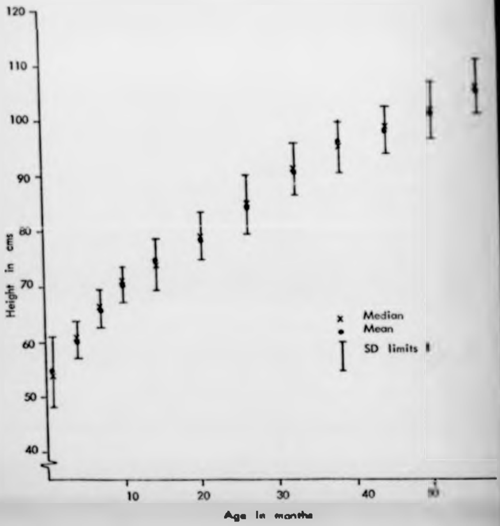
weights for both boys and girls lay above the standard for the first 6 months. It therefore seems unlikely that these children's birth weights were much below the Harvard standards. After 6 months the weights of boys and girls started to fall behind the standards. By the age of 12 months girls had a weight deficit corresponding to the 25th percentile of the standard. This deficit persisted and in subsequent periods they maintained an average weight at the 25th percentile level.

The boys' weight followed a similar pattern after the age of 6 months but by 12 months they were only 0.5 kg. lighter than the standard. It can be observed from Figure III.19 that by 18 months the difference between the Montserrat and North American boys amounted to 1.5 kg. Between 18 months and 24 months of age the boys' weight gain seemed to have slowed further since the median weight now corresponded to the 10 th percentile value, that is a lower percentile than that of the girls. From 2 years onwards the weight curve for boys was maintained at the 25th percentile level.

We may conclude from this graphical comparison that Montserratian children appear to have a growth rate corresponding to the Harvard standard for the first few months of life but after this time there are marked deviations from the expected growth lines for both boys and girls.

Figure III. 20.

HEIGHT OF MONTSERRAT CHILDREN , SEXES COMBINED
MEDIAN , MEAN AND SD OF THE MEAN.



If for the moment we set aside the usual conclusion that this reflects the development of significant malnutrition in the community at this age, we still have to recognize that the deviation from the standard line probably reflects an environmental effect since such sudden deviations from a smooth growth curve are unlikely to be determined genetically. Further analysis of the distributions of weight as well as the other indices at those periods of slow growth might help in determining the nature of the problem and whether this longitudinal type of analysis is appropriate.

Height For Age:

In Figure III. 20. the height for age distribution of the Montserrat pre-school population is illustrated. The median and the mean heights with standard deviations are plotted together for the sexes combined at each age interval. This graph shows that height is relatively well distributed in a Gaussian manner so that the mean values were very close to the median figures. Apart from the first age group, that is at 3 months, where the number of children was small the standard deviations remained consistent at 6 % of the mean values at each age interval.

Figure III. 21. demonstrates that between 0 months and 12 months boys were taller than the girls. There were statistically significant differences in length between the sexes at 3, 9 and 12 months (P>0.01), boys being taller than girls. The maximum difference between the mean heights at these ages was 3 cm. After the first year however, a completely different pattern emerged; the girls seemed to be taller than the boys. At 15 months and 25 months of age this difference varied from 0.58 cm. to 3.08 cm. and the differences were found to be significant at the 5 % level. At 26th months the boys' length again exceeded the girls' but the differences observed were small. The girls' length in fact followed the boys' very closely from 26th months to 4.5 years.

It is important to note at this stage that this pattern observed for girls is quite unlike any other data reported on healthy children. Davio et. al. (1972) noted that the difference in the height attained by two sexes varied in favour of boys during pre-school ages and the mean difference is found to be between 0.71 cm. and 2.20 cm. They reported an over-all difference of 0.80 cm. This finding might indicate that in Montserrat boys were more affected by adverse environmental conditions than girls and became more retarded in height.

In Figures III. 21 and III. 23. the comparison of height for age values of Montserrat pre-school children with Harvard standards is illustrated for both sexes separately. The boys' median heights from 1 month to

6 months of age are almost identical to the standard but a considerable deviation from this standard begins from the 6th month onwards. In the older age groups although the absolute difference between Montserratian and American boys seems to be small yet in terms of percentiles there appears to be a greater deviation for height than we observed for weight. Thus the median values for boys at 14, 18 and especially at 24 months were below the 3rd percentile for height. A marked "stunting" at this stage is therefore apparent. The median heights then shifted upwards from the age of 3 and were maintained between the 10th and 25th percentile subsequently.

The girls' median height values at 1, 3 and 6 months were slightly below the 50th percentile but as with boys a deviation from the standard becomes obvious later and the median values at 1 year and 18 months were almost at the 10th percentile level. Girls did not seem however to be as stunted as boys in height since they "grow" along the 25th percentile from 18 months onwards.

In summary therefore we have clear evidence for stunting in height in pre-school children with some indication that boys were more severely affected than girls. The importance of these observations will become apparent in subsequent discussion.

Figure III. 21.

COMPARISON OF HEIGHTS OF MONTSERRAT PRE - SCH. BOYS WITH PRE - SCH. GIRLS.

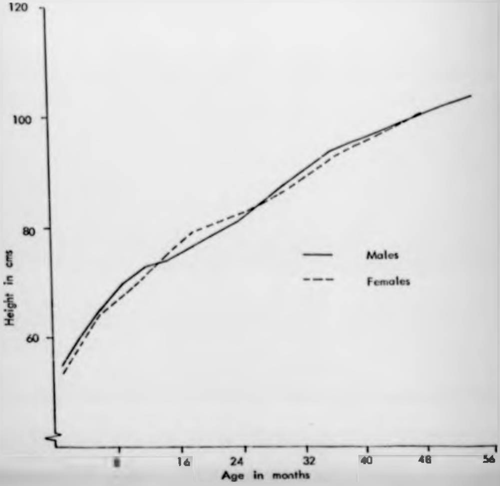


Figure III. 2b.

COMPARISON OF HEIGHT MEASUREMENT OF MONTSERRAT PRE - SCH. BOYS WITH HARVARD STANDARD.

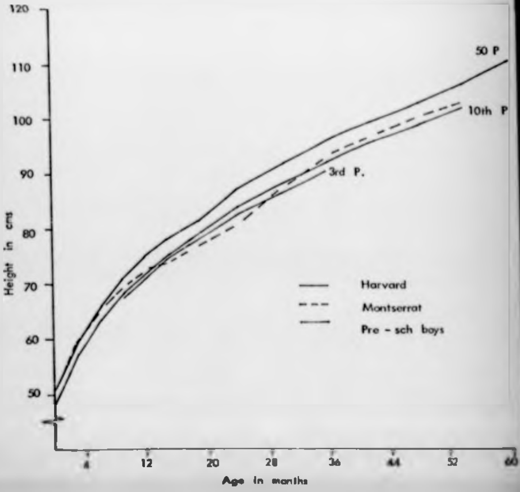
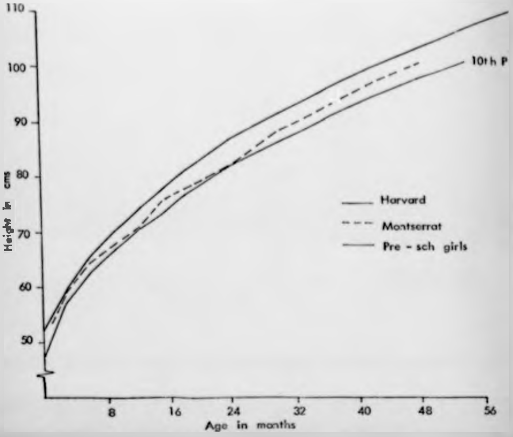


Figure III. 23.

COMPARISON OF HEIGHT MEASUREMENT OF MONTSERRAT PRE - SCH. GIRLS WITH HARVARD STANDARD.



Arm Circumference For Age

The distribution of arm circumference measurements of Montserrat children are represented in Figure III.24. for the two sexes combined. The range of distribution remained quite small with standard deviations which varied between 1.0 cm. and 1.4 cm. As in the case of other anthropometric measurements the standard deviation of the mean for the first age group was the largest and this might be due to the fact that in our series there were some very fat babies with fat arms within 0 and 3 months age group. For the rest of the age range the standard deviations were found to be in close agreement with those of healthy children (Robinow and Jelliffe, 1969).

During the first year an increase of 3 cm. was observed but from then onwards there was a relatively small change with age. This is similar to the changes seen in the measurements of healthy children and has also been observed by other workers in well nourished and moderately malnourished populations (Jelliffe and Jelliffe, 1969). Indeed after the age of 2 years a constant value has been suggested by Cook (1969) to simplify anthropometric data so that the age dependency problem does not arise.

In Figure III.25 we have plotted curves for the arm circumference against age for both sexes separately. Standards based on data obtained from healthy children reveal very small sex specific differences (Jelliffe, 1966;

Robinow and Jelliffe, 1969). In both the Wolanski and Robinow series sex differences were found to be only 2 % of the measurement in favour of boys. When arm circumference curves for Montserrat boys and girls were compared, differences were observed. Between 0 months and 6 months boys had bigger arm circumferences and the difference sometimes amounted to 1 cm. or 7 % of the mean measurement. At 6 months, however, girls attained similar values to boys and then in the latter half of infancy girls tend to have fatter arms than boys. Between 13 months and 24 months the mean arm circumference measurements for boys showed first a fall and then a rise while those of girls did not show a change. The values found for 4 and 5 year old boys were greater than girls. Despite occasionally large differences, for example of 1.6 cm. at 3 months of age, none of the differences in arm circumference measurements for boys and girls were found to be statistically significant. This reflects the variability of this measurement in Montserrat children.

For the analysis of arm circumference measurements of Montserrat children the standards prepared by Wolanski (Jelliffe, 1966) were used. Although these standards have been criticised by some workers in this field and attempts were made to smooth the curve by polynomial equations (Burgess and Burgess, 1969; El Lozy, 1969), it was decided to use the original Wolanski figures as they were given in the W.H.O. Handbook for the Assessment of Nutritional Status (Jelliffe, 1966).

A comparison of Montserrat arm circumference values with the standards is shown in Figures III.26 + 27. As in the case of weight and height, the arm circumferences of boys remained slightly above the standard from birth to 6 months of age. After 6 months no further increase in the arm girth occurred so that the median curve deviated from the expected increase shown by the standard. At 9 months the difference persisted in boys but there was a small increase by the age of 24 months. After the second year there appeared to be a linear rise in the arm circumference values but the median value remained below and parallel to the standard.

When we compared the arm circumference curves of girls with their standard we observed that their values were almost on the median standard cuve during the first 6 months and not above the standard as in the case of boys.

However, the arm circumference of girls between the ages of 6 months and 30 months did not increase at all until 36 months when the older girls were found to have a 7% increase in the arm measurement. Thereafter there was a very gradual increase.

Figure III. 24.

ARM CIRCUMFERENCE

Median mean and the SD of mean distribution for Montsrrat pre - sch. children, sexes combined.

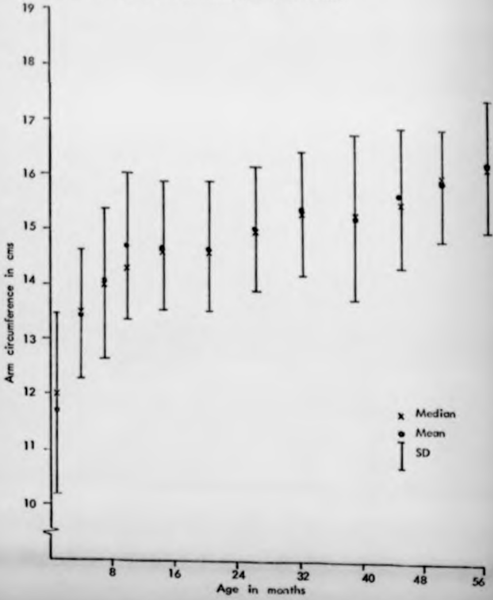


Figure III. 25.

COMPARISON OF ARM CIRCUMFERENCE MEASUREMENT OF MONTSERRAT PRE - SCH. BOYS WITH PRE - SCH. GIRLS.

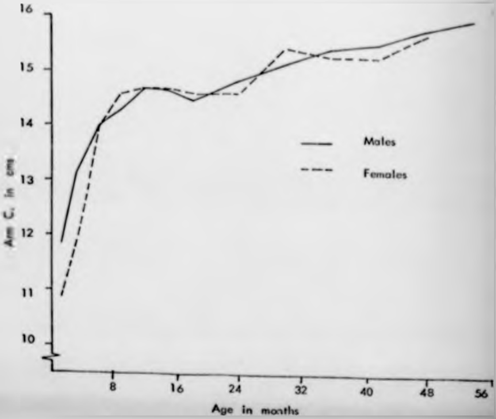


Figure III. 26.

COMPARISON OF ARM CIRCUMFERENCE MEASUREMENT OF MONTSERRAT PRE - SCH. BOYS WITH THE STANDARD.

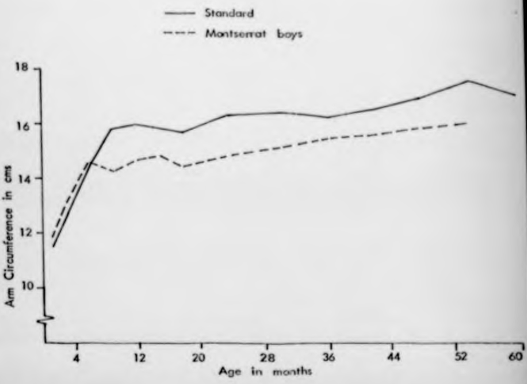
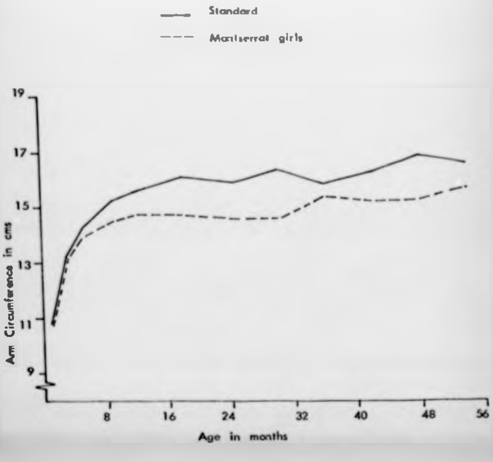


Figure III. 27.

COMPARISON OF ARM CIRCUMFERNECE MEASUREMENT OF MONTSERRAT PRE - SCH. GIRLS WITH THE STANDARD.



Muscle Circumference

Figure III.28. shows the mean, median and the standard deviations of muscle circumference for the Montserrat children. Like height, muscle circumference distribution is relatively normal with smaller standard deviations averaging about 8 % of the measurement. The slight differences between the mean and the median values could be due to the fact that this parameter is derived from arm circumference and triceps skinfold measurements with the latter showing a markedly skewed distribution.

In Figure III.29. a comparison of the muscle circumference values of boys and girls is illustrated. There was no statistically significant differences between the sexes. However, the boys' muscle circumference was greater than the girls' at all ages except 30 months. This pattern is in agreement with other data reported by Cheek (1968) showing that boys tend to have a greater lean body mass than the girls throughout infancy and childhood.

It becomes important to determine whether these differences between the sexes are nutritionally important or whether despite the evidence for a greater muscle mass in Montserrat boys they are still deficient in muscle when compared with standards. Figure III. 30. shows that despite the slightly greater muscle mass of boys this sex in fact showed the greater decrement at 18 months when compared with the male standards.

This standard was calculated from the arm circumference standards of "normal" Polish boys reported by Wolanski and triceps skinfold thickness measurements of British children (Hammond, 1955a; Tanner and Whitehouse, 1962). This approach was first used by Jelliffe. These derived values which imply a greater muscle mass for boys in fact deal with differences of only up to 0.5 cm. Yet these differences have been confirmed by larger studies (Frisbanco, 1974). Thus the deficit in the muscle circumference for boys is not a reflection of the choice of standards and presumably represent either a nutritional effect or a genetic difference between Montserrat and Caucasian children.

Triceps Skinfold Thickness:

In Figure III.31. the mean, median and the standard deviations of the triceps skinfold thickness measurements of Montserrat children demonstrate that these values were very different from the other indices since there was no evidence of a normal distribution. The differences between the mean and median values were statistically significant ($P > 0.05$) with median values always less than the means. Although the distributions were very skewed no log transformations were made since expressing the data in absolute terms is often more valuable and meaningful to those employing them than the use of some mathematical derivation of the values themselves. This choice of presentation also helps in understanding the practical importance of measurement errors in the evaluation of triceps skinfold results.

In contrast to most other anthropometric indices we found that the Montserrat girls usually had a triceps skinfold thickness which was greater than the boys (Figure III.13.). Only in the first 3 months was there an appreciable difference in favour of the boys.

The comparison of Montserrat childrens' skinfold measurements with the standards raised the question of ethnic differences which will be considered later.

From the foregoing analysis, it is clear that there were differences between the values of anthropometric measurements obtained for girls and boys on many occasions and these differences were sometimes statistically significant. Therefore it seemed desirable to consider the two sexes separately whenever possible despite the widespread use of combined data for preschool children. We did have the problem, however, of not having enough children in each group to be able to continue all our statistical analysis with the sexes separately. We also needed to combine the sexes wher comparisons were made with other data presented in a similar fashion.

Figure III. 58.

MONTSERRAT PRE - SCH. POP. SEXES COMBINED

Muscle circumference calculated from Triceps Sk. Th. and Arm C.

Distribution of measurements.

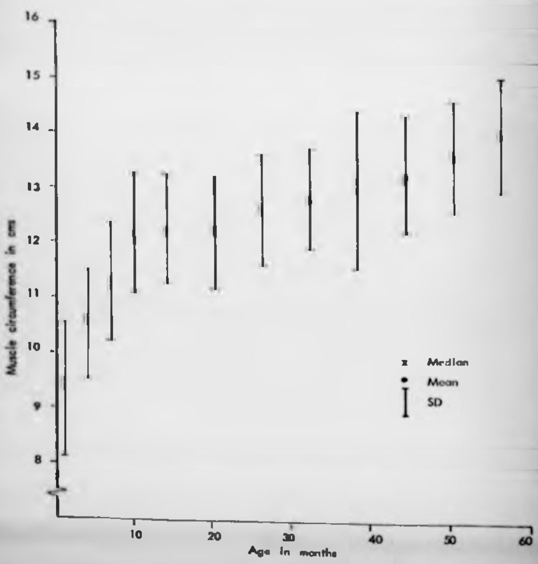


Figure III, 29.

COMPARISON OF MUSCLE CIRCUMFERNECE MEASUREMENTS OF MONTSERRAT PRE - SCH. BOYS WITH PRE - SCH. GIRLS.

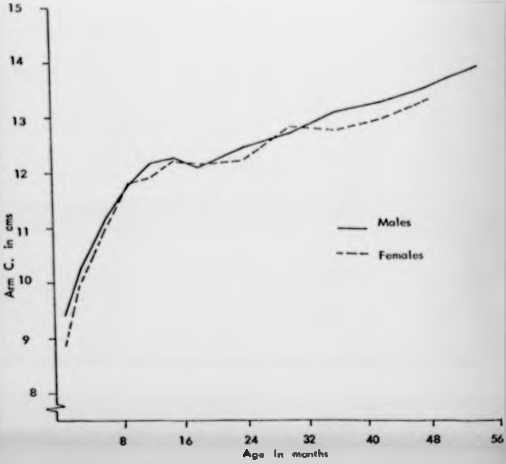


Figure III. 9b.

COMPARISON OF MUSCLE CIRCUMFERENCE MEASUREMENT OF MONTSERRAT PRE - SCH. BOYS WITH THE STANDARD.

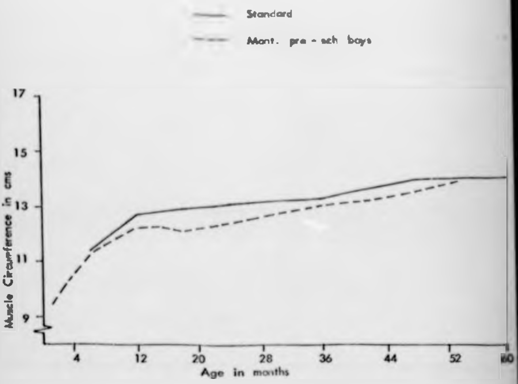


Figure III. 31.

COMPARISON OF MUSCLE CIRCUMFERENCE MEASUREMENT OF MONTSERRAT PRE - SCH. GIRLS WITH THE STANDARD.

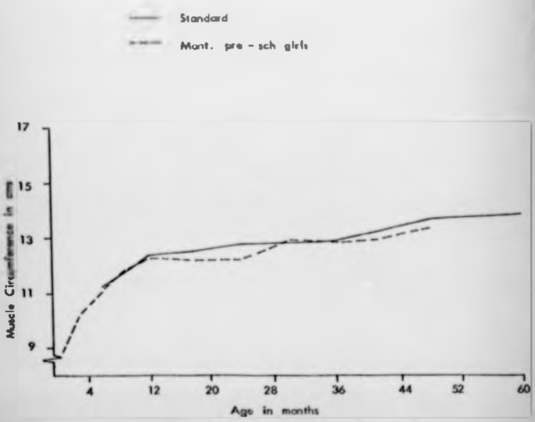


Figure III. 13.

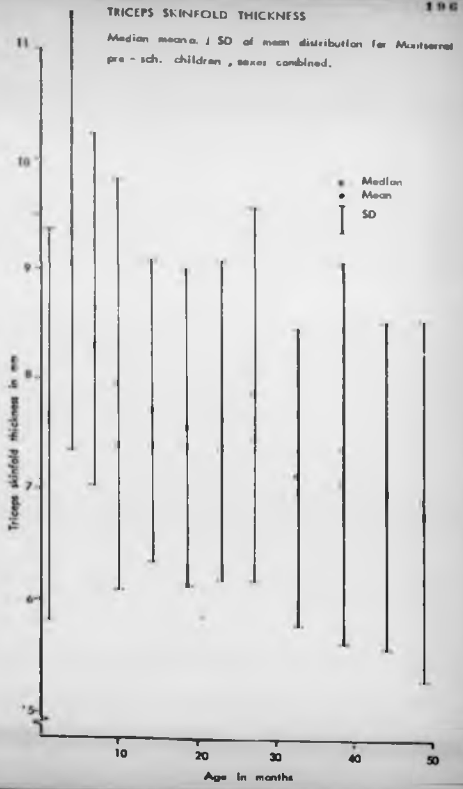


Figure III. 33.

COMPARISON OF TRICEPS SKINFOLD THICKNESS MEASUREMENTS OF PRE - SCH. BOYS AND GIRLS.

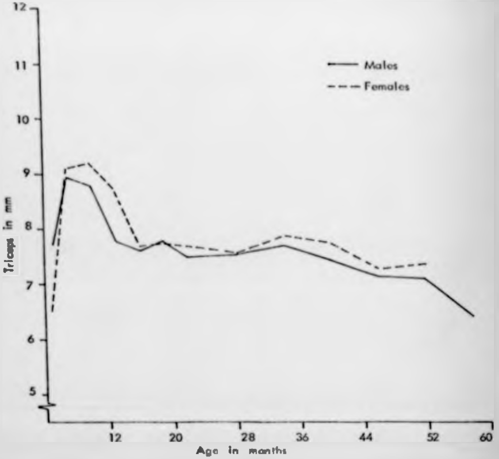


Figure III. 35.

COMPARISON OF TRICEPS SKINFOLD THICKNESS OF MONTSERRAT PRE - SCH. BOYS WITH THE STANDARD.

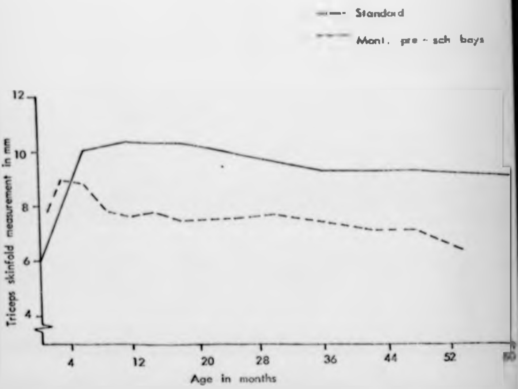
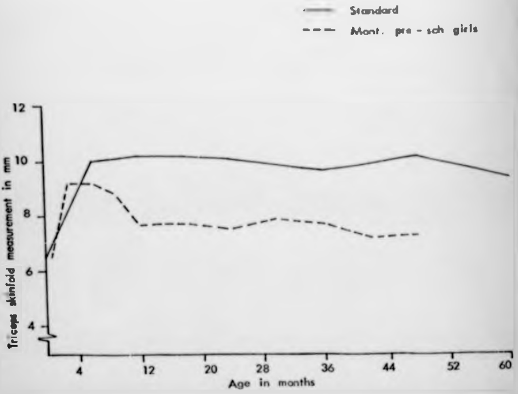


Figure III. 35.

COMPARISON OF TRICEPS SKINFOLD THICKNESS OF MONTSERRAT PRE - SCH. GIRLS WITH THE STANDARD.



D. A[illegible]REAT CHILDREN EXPRESSED AS A PERCENTAGE OF THE STANDARD

Anthropometric measurements were also expressed as the percentage of the relevant standard and the proportions of children falling below or above the various 10 % or 5 % levels of the standard are presented.

This method of analysis is essential when the purpose of the survey is to determine the incidence or prevalence of Protein Energy Malnutrition (PEM) in a defined community by classifying the cases quantitatively in relation to the severity of the condition.

The anthropometric measurements of each child namely, height, weight, arm circumference and triceps skinfold thickness as well as the calculated indices such as weight for height and muscle circumference, were expressed as the percentage of the standard. Then the proportions of children falling into different percentage levels of the standard was calculated.

The sexes were combined and the children grouped into 6 monthly age intervals for the first year of life and then in yearly intervals up to 60 months.

Weight for Age:

The weights of children were expressed as a percentage of the reference weight (Harvard standards) at each corresponding age for each sex. Table III.16. shows that 56.3 % of pre-school children between 0 and 11 months of age were above the standard weight. This proportion begins to fall after the 11 th month and then varies between 25.4 % and 35.5 %. The proportion of children whose weight for age was below 80 % of the standard was only 3.6 % for the group between 0 months and 11 months, but increases to 17 % in the 12-23 months old group. This table also illustrates the fact that a greater proportion of children were clustered between 99 % and 80 % of the standard after the first 6 months of life the proportions varying between 45.5 % and 56.8 %.

Height For Age:

Table III.17. summarizes the distribution of children around different levels of the standard height for age, the percentage groups being arranged in 10 % and 5 % intervals. The proportion of children whose percent height for age was above the standard was lowest for the group between 12 and 23 months. The mean height for age values for the 0 - 6 months age group was either above or the same as the standard so they had presumably grown initially as well as children in developed countries.

Among Montserrat pre-school children there seemed to be very few tall children. 63.0 % of the total pre-school population were between 99 % - 90 % of the standard but only 4.4 % were below 90 % of the standard. However, 20 % of the total sample fell below 95 % of the standard. The proportions of children below this level ranged from 30 % for the 12 to 23 month olds to 3 % for the 0 - 6 month olds.

Weight For Height:

Calculations of the weight for height were based on weight height standards given in the WHO Monograph (Jelliffe, 1966). Optimal weight for height was obtained using the child's actual height and reading the corresponding expected weight for that height in the tables. Percentage values using the actual weight against the theoretical weight for height were then calculated.

Table III.11 gives the distribution of children at different levels of the standard weight for height. 71.2 % of the total sample fell above the 95th % of the standard limit, 17.4 % were between 90-95 % of the standard and 11.5 % below 90 % of the standard weight for height.

In our series, the 12 - 23 months old group had the highest proportion that is 14.5 %, below 90 % of weight for height.

Our results are very similar to those of Seoane and Latham (1971) who analysed a sample of children from Bogota, Colombia.

Arm Circumference, Triceps Skinfold Thickness and Muscle Circumference:

These measurements were expressed as a percentage of the standards as explained above. The distributions of the proportions of children around different levels of the standard are given in Tables III. 19. , III. 20 and III. 21 . In our series as explained in the previous section, we obtained very low values for triceps skinfold thickness measurements. The numbers of children with arm circumferences above the standard shows a variation with age which was similar to the other measurements. For the 0 - 6 months age group 50 % of the children were above the standard. This proportion dropped markedly for the subsequent age groups while the proportion below 90 % of the standard increased from 8.2 % to 28.0 %.

For the 0 - 6 months age group again only a small proportion of children had muscle circumference much below the standard and thereafter an appropriate proportion had values which again fell well below the 100 % standard point.

Table III.16.

The Distributions of the Proportions of Montserrat Pre-School Children Falling at Different Levels of the Standard Weight for Age.

Age Groups in Months	Total number of Children	Distributions of Percentage Weight for Age																	
		110% & above		109% - 100%		99%-95%		94%-90%		89%-85%		84%-80%		79%-70%		69%-60%		[illegible]	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0-5	85	28	33.0	19	22.3	13	15.3	7	8.2	6	7.0	9	10.5	2	2.2	1	1.2	0	0
6-11	99	24	24.0	20	20.0	8	8.0	15	15.2	14	14.0	6	6.0	10	10.0	2	1.0	1	1.0
12-23	207	12	5.7	41	19.7	27	12.9	38	18.3	39	18.7	14	6.8	27	13.0	8	3.8	1	0.4
24-35	191	18	9.3	44	23.0	25	13.0	40	20.9	24	12.6	20	10.4	19	9.8	0	0.0	1	0.5
36-47	231	16	6.9	58	25.0	46	19.9	36	15.5	38	16.3	18	7.8	16	6.9	3	1.2	0	0.0
48-59	218	17	7.8	54	27.7	34	15.6	42	19.2	40	18.0	17	7.8	11	5.0	3	1.3	0	0.0
0-60	1031	115	11.1	236	22.8									84	8.1	16	0.1	3	0.03

Table III.17

The Distributions of the Proportions of Montserrat Pre-School Children Falling at Different Levels of the Standard Height for Age.

Age Groups in Months	Total Number of Children	Distributions of Percentage Height for Age													
		110% & above		109% - 100%		99% - 95%		94% - 90%		89% - 85%		84% - 80%		79% - 70%	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0-5	85	1	1.2	24	28.1	41	48.2	17	19.8	1	1.2	1	1.2	0	0
6-11	99	0	0	39	39.4	44	44.4	15	15.1	0	0	0	0	1	1.0
12-23	207	3	1.3	36	17.4	90	43.4	62	29.9	11	5.3	3	1.3	2	0.8
24-35	191	1	0.5	57	29.8	75	39.1	47	24.5	9	4.7	1	0.5	1	0.5
36-47	231	1	0.4	85	36.7	101	43.7	36	15.5	8	3.5	0	0	0	0
48-59	218	1	0.4	85	38.9	98	44.8	26	11.9	5	2.2	2	0.8	1	0.4
0-60	1031	7	0.6	326	31.6	449	43.5	203	19.6	34	3.3	7	0.6	5	0.4

Table III.19

The Distributions of the Proportions of Montserrat Pre-School Children Falling at Different Levels of the Standard Weight for Height.

Age Groups in Months	Total Number of Children	Distributions of Percentage Weight for Height											
		110% above		109% - 100%		99% - 90%		89% - 80%		79% - 70%		69% & below	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0-5	85	39	45.8	27	31.7	14	16.4	4	4.7	1	1.1	0	0
6-11	99	30	30.3	28	28.2	27	27.2	10	10.1	3	3.3	1	1.0
12-23	207	17	8.2	85	41.0	75	36.3	25	12.0	4	2.0	1	0.5
24-35	191	19	10.0	67	35.0	81	42.4	19	9.9	4	2.0	1	0.5
36-47	231	15	6.4	84	36.0	109	47.1	22	9.5	1	0.4	0	0
48-59	218	50	22.9	53	24.3	96	44.0	17	7.7	2	1.0	0	0
0-60	1031	170	16.4	344	33.3	402	39.0	97	9.4	19	1.8	3	0.2

Table III.19

The Distributions of the Proportions of Montserrat Pre-School Children Falling at Different Levels of the Standard Arm Circumference for Age.

Age Groups in Months	Total Number of Children	Distribution of Arm Circumference for Age									
		110% & above		109% - 100%		99% - 90%		89% - 80%		79% & below	
		No.	%	No.	%	No.	%	No.	%	No.	%
0-5	85	16	18.7	27	31.0	35	41.9	7	8.2	0	0
6-11	99	4	4.0	22	22.0	45	45.0	25	25.0	3	3.0
12-23	207	1	0.4	41	19.7	99	47.7	58	27.8	8	3.7
24-35	191	4	2.0	33	17.2	98	51.2	53	27.6	3	1.5
36-47	231	4	1.7	44	19.0	117	50.4	60	25.8	6	2.6
48-59	218	4	1.8	45	20.5	122	55.8	47	21.4	0	0

III. 1. COMPARISON OF THE ANTHROPOMETRIC RESULTS OF MONTSERRAT PRE-SCHOOL CHILDREN WITH DATA FROM OTHER CARIBBEAN ISLANDS

Since this thesis is concerned with the problems of interpreting and explaining anthropometric data, some of our analysis of the results will be presented in conjunction with the data available from other surveys conducted in the Caribbean.

These comparisons have a two-fold purpose:

a. To establish that we are not dealing with an isolated problem seen in a small island but with a series of findings found in many other Caribbean islands.

b. To show the extent to which assessment of anthropometric changes is confused by the choice of several different ways of expressing the data. These points will be illustrated by considering the anthropometric indices obtained in our pre-school survey.

A. <u>General background information about other nutritional surveys conducted in the Caribbean:</u>

During the last decade, the nutritional status of children in the Caribbean area has been investigated extensively. The studies carried out have been mainly concentrated to the larger islands: for example, Barbados (Standard, 1964; 1969; Cook, 1971), Jamaica (Ashcroft, Heneage, Lovell, 1966; Ashcroft and Lovell, 1966; Ashcroft, Lovell and Williams, 1965; Jolliffe and Dean, 1959; Gurney and Fox, 1971), Guyana (Ashcroft, Bell, Nicholson and Pemberton 1966), Haiti (Jelliffe and Jelliffe, 1960) and Trinidad (Jolliffe, Symonds and Jolliffe, 1960).

Smaller islands also been investigated. These are St. Kitts, Nevis and Anguilla (Ashcroft, Buchanan, Lovell and Welsh, 1966), St. Vincent (Ashcroft and Antrobus, 1970; Antrobus, 1971).

In the majority of the studies mentioned above, children of school age that is 5 - 15 years group have been investigated with cross-sectional surveys; school children were measured readily because they are accessible and adequate numbers can be measured within a short time span (Ashcroft and Lovell, 1966).

Some pre-school data from other Caribbean islands is however longitudinal and they will be used in conjunction with cross-sectional data to permit adequate comparisons to be made.

The following studies are to be compared with the data from the pre-school population of Montserrat.

1. St.Kitts, Nevis and Anguilla
2. St. Vincent
3. Jamaica

The reasons for selecting these studies are that the first two belong to small islands which have very similar socio-economic, geographical, cultural, ethnic characteristics to Montserrat. The data reported by those studies have also been collected relatively recently so that secular changes in growth are less likely to be important. All three studies were longitudinal.

A general outline of each study will be given at this stage since the methodological aspects of the studies are related to our later analysis.

St.Kitts, Nevis and Anguilla:

This study which was carried out by Ashcroft et. al. (1966) reported only the weights of infants and preschool children born in 1957 and 1958 in St. Kitts, Nevis and Anguilla and these figures were based on measurements made only on routine clinic attendance. The attendance rate at these clinics was reported as 90 % for the children living in St. Kitts and Nevis with a somewhat smaller percentage in Anguilla. Almost all of these children were as in Montserrat, of African origin. Most of the children included in the survey were followed up for 5 years until 1962 or 1963. Of the children who died all but twelve were excluded from the study. Multiple births and infants of low-birth weight were not excluded. For each subject, the median weights in monthly intervals up to 2 years and thereafter in 6 monthly intervals to 5 years were calculated from clinic records. Mean weights, percentiles and standard deviations were calculated for various age intervals.

Although the data collected by this method related to a longitudinal study, the presentation of the data was in a cross sectional form. Therefore this study is suitable for comparative purposes.

Figures III.36 and III.37. show the mean weights of boys and girls separately from Montserrat, St. Kitts and Nevis. Figure III.36 shows that although there were consistent differences in the weight attained by St. Kitts and Nevis boys when compared with Montserrat children yet the differences were small. Clearly all three islands have mean weights below the Harvard Standards.

Figure III.37 show almost the same pattern in weight of girls from these islands. St. Kitts girls again seem to be the lightest throughout the pre-school age span. Nevis girls have very similar weight values to Montserrat girls although the data from those islands were collected approximately 14 years before our survey. St. Kitts children seem to be nutritionlly disadvantaged since they are consistently lighter than Nevis and Montserrat children from birth until the end of the pre-school period but again all three islands show data below the Harvard Standards.

Jamaica Study:

Standard, Desai and Miall (1969) report the results of a longitudinal study of growth of 229 infants during the first year of their life. This group which was from a rural area was followed up for 4 consequent years. Fortnightly measurements were made on children until 2 years of age, then monthly until the age of 3, and thereafter at 3 monthly intervals to 5 years of age. The children who were not brought to the clinic for this examination were visited at their house within 3 days of the required time for examination. In the presentation of the results, distributions of weight and height were given cross-sectionally as mean values and standard deviations together with some percentile values.

This study from a large island is included since it helps to emphasize the similarities of weight in different parts of the Caribbean and also shows that an enormously expensive and meticulously conducted survey is presented in such a way that few useful comparisons can be made and the analysis of the data is only very limited in scope.

In FiguresIII.36&39 the weights of children from Jamaica and Montserrat are compared. The values for boys and girls are plotted on separate graphs. The weights of Jamaican boys are consistently below the Montserrat group, especially after the 2nd year. The

Jamaican weights fall below the values found in the smaller Caribbean islands and do not show a recognizable catch up phase until 48 months. The weights of girls on the other hand, are below Montserrat values, showing a considerable fall after 28 months. Among groups compared, girls are relatively less deficient in weight than the boys.

In the case of height, Montserrat boys show a similar trend to their Jamaican counterparts (Figure III.36).

Although one might like to infer that studies conducted within a 10 year period on different islands are comparable there are good reasons for believing that secular trends within the Caribbean might be more rapid than, for example, in the United Kingdom. Thus in the United Kingdom school childrens' height is social class dependent but the range of weights between the social classess seem to be diminishing as the lower classes "catch up" with those from social class A and B. Similarly if economic conditions improve as they appear to have done in the Caribbean over the last 10 years, then changes in weight might rapidly reflect these improved conditions if the nutritional status of the children were initially well below the genetically determined maximum. With this in mind we have included another small study from the small island St. Vincent conducted almost at the same time as that in Montserrat

Figure III. 3 .

COMPARISON OF WEIGHT OF PRE - SCH. BOYS FROM VARIOUS CARIBBEAN ISLANDS.

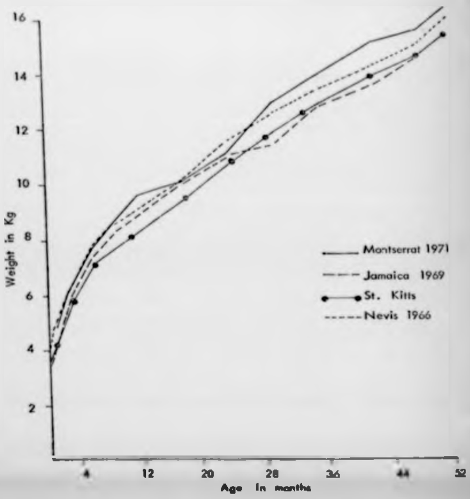
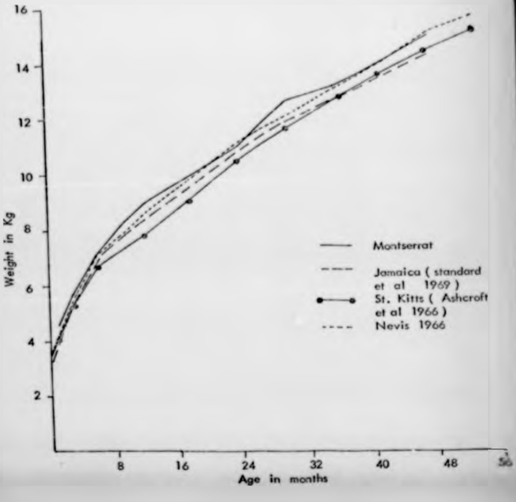


Figure III, 37.

COMPARISON OF WIGHT OF PRE - SCH. GIRLS FROM VARIOUS CARIBBEAN ISLANDS.



since the information from this study was also presented in such a way that a comparison of mean weights was possible.

St. Vincent:

Data from the island of St. Vincent was collected by Antrobus (1971) between 1967 and 1968 and initially started with 150 children; it ended in 1969 with 300 children, the periods of follow up ranging from a minimum of 1½ years to 3½ years. It was estimated that 80 % of the children population within the designated area were included in the study. When children failed to attend for measurement, efforts were made to collect the data at home. Consequently, the number of children with complete records at various ages varies and the study became a mixed longitudinal study. Weights, heights and head circumference measurements were taken; on average 18 measurements were made on each child in the 3 year period.

The results are given as means and standard deviations of the mean weights and heights and head circumferences. The results on boys and girls were combined although mean weights were given for sexes separately; this data was tabulated cross sectionally.

In general we can conclude that St. Vincent values are similar to those from Montserrat with St. Vincent boys occasionally exceeding the mean weights for Montserrat boys but with the girls having means which are consistently below the Montserrat girls' figures.

In conclusion, it seems reasonable to state that almost all groups from all islands start off by gaining weight rapidly and grow was well as their European counterparts up to 6 months of age. This fact is valid for both boys and girls. After this age children in all the islands fall below the standard values and the mean heights and weights are very similar. Thus conclusions from our analyses of the Montserrat children will probably be applicable to children in most Caribbean islands.

Figure III. 36.

COMPARISON OF HEIGHTS OF MONTSERRAT PRE - SCH. BOYS
WITH DATA FROM JAMAICA AND St. VINCENT.

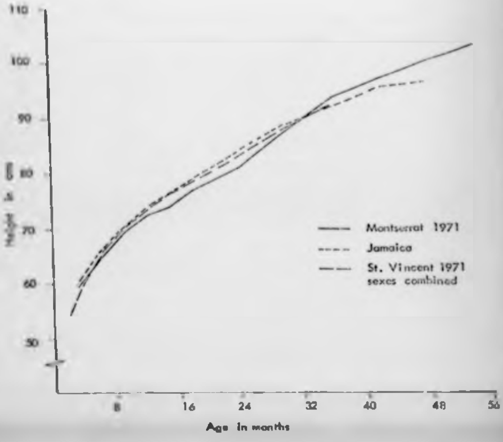
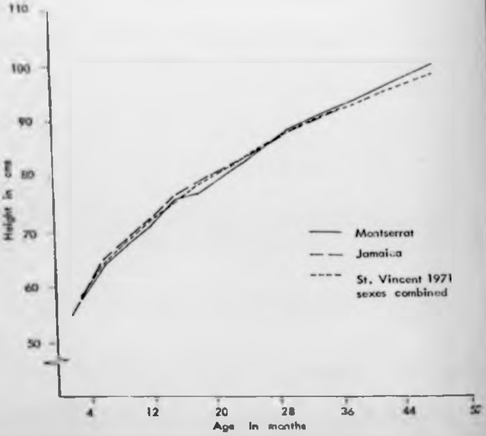


Figure III. 39.

COMPARISON OF HEIGHTS OF MONTSERRAT PRE - SCH. GIRLS WITH DATA FROM JAMAICA AND St. VINCENT.



B. A comparison of the anthropometric results of Montserrat pre-school children with recent studies from Jamaica and Barbados; data expressed as the percentage of the standard.

In this section we shall deal with more detailed comparison of data from other anthropometric studies carried out in recent years in the Caribbean. Since the mode of expressing results has changed in the last 10 years this has also to be taken into account. We are not therefore able to compare the results from all the islands as one might wish. However the purpose of the later series of studies was to look at the distributions of values for height and weights etc. with the specific intention of identifying those children with "malnutrition".

The nutritional status of two other West Indian populations from Jamaica and Barbados will be compared with the data from Montserrat. For this comparison the anthropometric measurements were all expressed as the percentage of the standards of reference mentioned in III. 2. D. In the analysis of data from Jamaica and Barbados, Harvard Standards were also used as a base-line and permit comparison with Montserrat data. It is remarkable, however, that the authors, all members of the Caribbean Food and Nutrition Institute have reported their data in such a manner that no comparison with earlier data is possible. Thus secular trends cannot be observed . The somewhat dogged approach to the presentation whilst ensuring general acceptance of this format categorise children into grades of malnutrition without any attempt to show the limitations of this approach.

The actual anthropometric measurements such as height, weight, arm circumference and triceps skinfold thickness as well as muscle circumference, derived from arm circumference and triceps skinfold thickness, were converted into a percentage of the expected measurement at that age.

An assessment of the prevalence of PEM has been made by calculating the proportions of children with measurements corresponding to the third percentile of the standards. This is a fundamental concept which will be analysed later. Tables illustrating the different proportions of children around different levels of the standard in each island were constructed in a manner similar to those used by the Caribbean Food and Nutrition Institute (Gurney, Fox and Niall, 1972 ; Cook, 1972b).

These studies were now comparable since they are carried out during the same period, in 1970 and 1971 and were of cross sectional type. Although we do not possess sufficient information about the exact socio-economic situation of each child, the basic environmental factors affecting growth and development may be similar for these different islands making a comparison both appropriate and informative; in particular since nearly all the children from all three islands are Negroid and of mixed West African ancestory, genetic differences in growth capacity are unlikely to occur.

The values corresponding to each third percentile of the standards were taken by the C.F.N.I. as equivalent to 90 % of standard for the height for age; 80 % for the weight for age, 80 % for the arm circumference for age, 80 % for the calculated muscle circumference for age and 7.0 and 6.0 mm. for triceps skinfold. The choice of the 3rd percentile was based on the knowledge that only 3 % of the children from a healthy population would fall below this level, any proportions more than 3 % would then indicate growth failure within the community and a presumptive diagnosis of malnutrition (Gurney, Fox and Miall, 1972).

The Jamaica study of the nutritional status of children was undertaken in 1970 and covered a sample of 489 children between the ages of 0 months and 4 years in 3 urban and 7 rural areas of Jamaica (Gurney, Fox and Miall, 1972). Weight, height, head, chest and arm circumference as well as triceps skinfold thicknesses of children were measured by techniques as explained in the WHO Monograph (Jelliffe, 1966).

The Barbados study was also carried out in 1970 by Cook (1972) and covered members of 651 households selected statistically. Anthropometric measurements were made on all members of the households with clinical examination of any subject who showed signs of malnutrition. The techniques and the choice of measurements were similar to the Jamaica and Montserrat studies.

In both the Jamaican and Barbados surveys the results on male and female children below the age of 5 years were combined together for the final analysis. Gurney et. al. (197) did this because they found no evidence of different growth rates between the sexes in Jamaica. Although in our previous analysis in section III. 3.A. we have established differences in heights and weights between the sexes at various age groups, we have pooled the results of both sexes so that a comparison from those 3 islands can be made.

Although Gurney et. al. (1972) originally analysed Jamaican urban and rural groups separately no similar analysis was possible in either Montserrat or Barbados. The sample of children from Barbados is relatively small and in Montserrat 2/3 rds of the population lived in rural areas but probably went to school in Plymouth, the capital city. It was not possible to collect the relevant data on the origin of each child, whether they lived in rural or urban areas nor accurate information about their socio-economic level during our rapid survey. As a result, we used the combined figures for urban and rural groups from Jamaica.

Weight for Age:

Table III. 22. show the proportions of children from the three islands, classified into 4 percentage groups of the standard. The proportion of Jamaican children between the ages 0 and 11 months above the standard weight for age is greater than in the other 2 islands.

It is of interest that in Jamaica it is the urban children in particular who increase the proportion of the children above the standard weight for age. 20 % of the children in this group came from urban areas of Jamaica.

When the children between 0 and 11 months of age are divided into 2 six monthly age groups it becomes clear that children of 0 - 5 months put on weight remarkably well in all three islands there being more than 50 % of the children at or above the standard weight for age. On the other hand, the proportion in this high ranking group decreases to 20 % between the ages of 6 to 11 months. This pattern of weight for age distribution is similar both in Montserrat and Jamaica but is not seen in Barbados. However the numbers studied were small. Although the comparison was made among children measured cross sectionally it is quite evident that at older age groups, greater proportions of children have values below the standard. Table III. 22 shows that when the first year group is excluded, large proportions of children fall between 99 %-80 % of the standard.

The authors of Jamaica and Barbados surveys accepted 80 % of the standard as the cut-off point for weight for age and have diagnosed mild--moderate PEM among the group whose weight for age is below that level. The proportions of children falling below 80 % of the standard is greatest in all islands at 12-23 months of age group.

Height For Age:

In Table III. 23. the proportion of children are grouped according to the different levels of the percentage standard height for age. The proportion of children from Jamaica at or above the standard height for age is greatest for the 0-11 months age group. This proportion falls from 53.2 % to 23.4 % in the second year and then decreases gradually with age. The children in Montserrat and Barbados have similar number in this height group in infancy and a X^2 test showed no statistically significant differences between the proportions of children in the different height categories in Montserrat and Barbados at any pre-school age.

Table III. 20.

The Comparison of the Proportions of Pre-school children from Montserrat, Jamaica and Barbados in different age groups falling at different levels around the Harvard standard of weight for age.

Ages in months	No. in each age [illegible]			No. of children of [illegible] in different % levels around standard: 90 and over			[illegible] - 90 %			70% - 80%			below 60 %		
months	J	M	B	J	M	B	J	M	B	J	M	B	J	M	B
0 - 11	120	184	34	53.	49.4	35.0	33.4	42.1	29.0	11.9	8.0	29	1.2	0.5	6
12- 23	139	207	51	16.	25.6	23.0	51.0	57.0	61.0	19.8	16.9	16	2.6	0.5	--
24- 35	117	191	52	13.	32.4	23.0	71.3	57.0	63.0	16.3	10.0	14	0.7	0.5	--
36- 47	114	231	58	11.	32.0	24.0	64.3	59.7	59.0	19.3	8.2	15	0	0	2
48- 59	--	218	53	--	32.5	21.0	--	61.0	72.0	--	6.4	7	--	0	--
Total	490	103.	248	23.	34.0	24.6	57.	56.8	58.9	16.8	9.7	15.	1.1	0.3	1.2

J= Jamaica
M= Montserrat
B= Barbados

Table III. 2[illegible]

The Comparison of the Proportions of Preschool Children from Montserrat, Jamaica and Barbados in different age groups falling at different levels around the Harvard standard of Height for Age.

Age Group in months	No. of children in each age.			% of age group in different % levels around St. Height for Age														
				100% and over			99% - 95%			94% - 90 %			89% - 85 %			below 85 %		
	J	M	B	J	M	B	J	M	B	J	M	B	J	M	B	J	M	B
0 - [illegible]	120	84	34	53.2	34.7	34.[illegible]	30.9	46.[illegible]	40.0	[illegible]	[illegible]7.[illegible]	20	3.7	0.5	6.0	0.6	[illegible].0	--
[illegible]2- 23	[illegible]39	207	5[illegible]	23.4	[illegible]8.8	33.[illegible]	43.9	43.4	37.0	[illegible]	30.0	27	4.7	5.3	---	3.7	3.0	[illegible]
24 -35	[illegible]27	[illegible]	52	21.7	30.3	27	40.2	39.2	50.0	29.4	24.6	[illegible]9	6.3	4.7	4.0	1.8	[illegible].0	--
36 -47	[illegible]4	21[illegible]	58	21.5	37.2	39	42.5	43.7	[illegible].0	27.4	[illegible]5.6	24	4.5	[illegible]	3.0	3.8	0	3
48 -59	---	[illegible]2.8	53	--	39.4	38	--	45.0	[illegible]2.0	--	[illegible]1.9	[illegible]1	---	2.3	4.0	--	1.3	6

Table III. 22.

The Significance of the Difference of the Proportions of children from Montserrat, Jamaica and Barbados whose weight for age was below 80 % of the standard.

Age in months	No. of children in each sample			Montserrat X Barbados		Montserrat X Jamaica		Jamaica X Barbados	
	M	J	B	χ^2	P	χ^2	P	χ^2	P
0 - 11	120	184	34	6.75	0.05	4.24	0.05	9.84	0.01
12 -23	139	191	51	17.68	0.001	29.50	0.001	1.24	0.05
24 -35	117	207	52	15.60	0.001	36.30	0.001	2.35	0.05
36 -47	114	231	58	4.70	0.05	13.84	0.001	1.05	0.05
48 -59	---	217	53	2.81	0.05	---	---	---	---
Total	490	1030	248	13.13	0.01	23.19	0.001	0.35	0.05

Table III. 23.

The Significance of the difference of the proportions of children from Montserrat, Jamaica and Barbados whose height for age was below 90 % of the standard.

Age in months	No. of children [illegible]			Montserrat X [illegible]		Montserrat X [illegible]		Jamaica X Barbados	
	J	[illegible]	[illegible]	X^2	P	X^2	P	X^2	P
0 - 11	120	184	35	0.91	0.05	15.60	0.01	4.36	0.05
12- 23	139	207	51	5.14	0.05	1.29	0.05	2.08	0.05
24 -35	117	191	52	2.01	0.05	3.61	0.05	3.80	0.05
36 -47	114	231	59	4.92	0.05	16.00	0.001	6.30	0.05
48 -59	---	218	53	1.05	0.05	---	---	---	---
Total	490	030	248	1.10	0.05	3.06	0.05	1.29	0.05

III. 4. WEIGHT FOR HEIGHT RELATIONSHIP

The relationship between weight and height has often been based on the expression of body weight of an individual as a percentage of the average weight of persons of the same height, age and sex in the population to which he belongs (Keys et. al., 1972). This however requires that one has a suitable reference standard. In Section I.7. weight for height standards have been described.

Before we present our data from Montserrat which is analysed in terms of weight for height, it seemed appropriate to consider the way in which the standards for comparison were prepared and to assess whether discrepancies in the statistical methods are a cause for concern or not. This was particularly important since the pre-school age group weight for height tables which are in use, proved on careful analysis to have been constructed in a statistically erroneous manner.

A. Techniques Previously Used In Preparing Weight For Height Tables:

Frequency distributions of weight according to both height and age form the most accurate method for the determination of the weight for height relationship (Van Wieringen, 1972). However, this method requires a fairly large sample of children because the number of sub-groups is large.

The weight for height or length tables reported by Baldwin-Wood (1923), Scott (1961) and by Van Wieringen (1972) were all constructed by the frequency distribution method. In all these three, the samples used were large enough to allow sub-grouping. However, there are considerable differences between them.

Scott's tables of weight for height do not take age into account. Height grouping is made in 5 cm. intervals where the corresponding mean weight for that interval is calculated for separate sexes. In the Baldwin-Wood tables heights were given in 1 cm. intervals and weights for each height interval were given for both sexes separately in one yearly age groups. The Dutch tables also give the median as well as the 10th and 90th percentile weight values for 2 cm. height or length intervals. During infancy the ages are grouped quarter yearly, for children between 1 and 4 years of age , weight for height values were given in half yearly intervals.

As the most widely accepted reference book, the WHO Monograph (Jelliffe, 1966) gives various standards as a reference base. The weight for height tables given in this Monograph are taken from various sources: for adults the Metropolitan Life Insurance; for school children the Baldwin-Wood tables; and for pre-school children a modified version of Harvard standards.

We wanted to assess the validity and the usefulness of the Baldwin-Wood and Harvard standards by comparing them with the Dutch standards which are based on more recently collected data and are analysed more fully.

It must be remembered that the Harvard weight and height tables for pre-school children are the results of a longitudinal study and reported as median weights and heights for age separately as well as values corresponding to the 3rd, 10th, 25th, 75th, 90th and 97th percentiles. These are given without any values for standard deviations of the mean measurement. Jelliffe (1966) used both weight for age and height for age figures obtained from the Harvard standards and then proceeded with these to construct a weight for height standard independent of age for the pre-school children.

To construct weight for height tables Jelliffe pooled all of the height for age values given in 7 percentile groups together and listed them in an ascending order starting from 50 cm. in 1 cm. intervals. The corresponding weight values from the same height percentile group were then given as the weight for that height because he assumed that the weight of a child whose height is on the 25th percentile would be along the same percentile level. This approach seems to have serious drawbacks since it assumes that all children with a 25th percentile height also had a 25th percentile weight. This confounds the problem since a very tall but thin child could not be represented nor would it give the true 50th percentile value for that specific height.

If the weight for age and height for age had been given in monthly intervals by Harvard standards this approach would probably be less in error as this method of expression ignored any effect of age on height and weight relationship.

Ideally Jelliffe should have used polynomial equations based on the arithmetic means of height and weights taking into account the standard deviations and standard errors but on inspecting his tables carefully it becomes obvious that this has not been done.

We therefore felt that it would be useful to find out whether Jelliffe's approach would be seriously in error.

N. A Comparison Of The Jelliffe Analysis With That Of The Dutch Standards:

We decided to use the Dutch standards for this comparison since in these tables weights and heights of the same children are presented in terms of age and sex as well as in terms of weight for height with frequency distributions of weights at specific height intervals. Thus the Dutch data presented values in such a way that a Jelliffe type of calculation could be performed and compared with Van Wieringen's analysis of the same data.

To make a Jelliffe type of analysis the sexes were combined by taking arithmetic means. This was slightly different from Jelliffe's approach since from an inspection of his table it is clear that he has arbitrarily chosen girls' or boys' data if it helped to achieve successive increases in height from which he could then obtain the corresponding weights in the way described already.

Table III. 24. compares some values presented by the two methods. A paired "t" test was applied to see if there were significant differences between the weights found by the two different methods for a specific length interval.

A close inspection of Table III. 24. shows that

Table III.24

A Comparison of Jolliffe and Van Wieringen Methods For Constructing Weight For Height Standards in Pre-school Children. Data from Dutch Standards.

Height in 1 cm. intervals	Dutch data for pre-school children		
	"Jolliffe" Method (1)	"Van Wieringen" Method (2)	Difference between Methods in gm.
50-51	3.283	3.320	37
52-53	3.628	3.720	92
54-55	4.084	4.140	56
56-57	4.625	4.620	5
58-59	5.238	5.090	148
60-61	5.567	5.530	37
62-63	6.220	6.000	220
64-65	6.625	6.680	55
66-67	7.370	7.440	70
68-69	8.004	7.865	139
70-71	8.330	8.900	570
72-73	9.000	9.400	400
74-75	9.900	9.750	150
76-77	10.100	10.570	470
78-79	10.500	11.000	500
80-81	11.400	11.700	300

Table III. 24. continued

Height in 1 cm. intervals	Dutch data for pre-school children		
	"Jelliffe" Method (1)	"Van Wieringen" Method (2)	Difference between Methods
82- 83	11.400	11.900	500
84- 85	12.300	12.700	400
86- 87	12.300	12.800	500
88- 89	13.600	13.500	100
90- 91	13.400	13.900	500
92- 93	14.200	14.500	300
94- 95	15.400	15.100	300
96- 97	14.700	15.300	600
98- 99	15.700	15.800	100
100-101	16.500	15.600	900
102-103	16.500	17.300	800
104-105	17.400	17.500	100
106-107	18.900	18.600	300
108-109	18.300	18.500	200

(1) Mean weight for age for corresponding percentile length in kg. units.

(2) Frequency distribution of weights for height for age in kg. units.

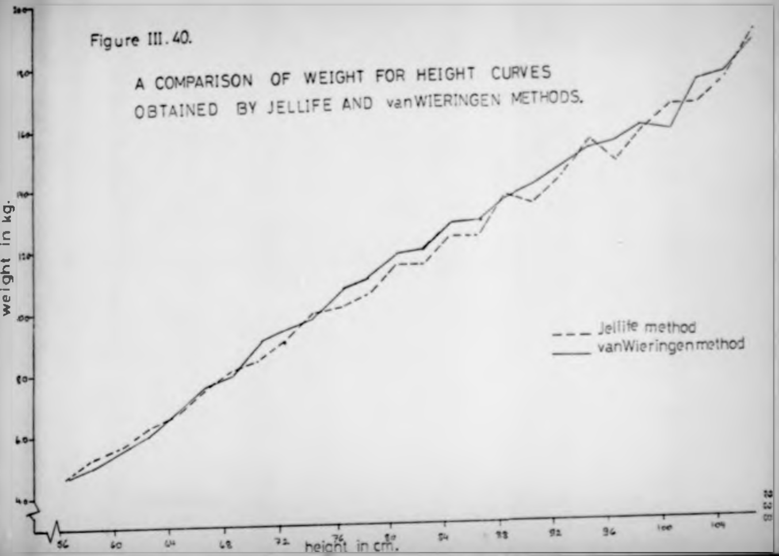


Figure III.40.

A COMPARISON OF WEIGHT FOR HEIGHT CURVES OBTAINED BY JELLIFE AND vanWIERINGEN METHODS.

there are often substantial differences between the two methods with differences ranging from 0 to 600 grams in children measuring 90-99 cm. This difference might of course make a very substantial difference to the classification of a child as "malnourished". The paired "t" test shows that there was no consistent trend when all the values are grouped. However some specific heights, for example, at those heights observed in 1-2 year old children that is, 70-80 cm. (see Figure III. 40.) the standards obtained by Van Wieringen's method were nearly always greater than by the Jelliffe's technique. Thus the choice of Jelliffe's method strictly speaking leads to an underestimate of the deficit in weight for height in precisely those children classically considered to be most prone to malnutrition. For example, a child who measured 99 cm. and weighed 12.5 kg. would be 85.0 % of the standard by the Jelliffe method but only 81.7 % by the Van Wieringen's method. If it was decided that 85.0 % should be a cut off point, delineating those with malnutrition from the "normals" then the child would be incorrectly classified using the Jelliffe method.

It could be argued however that since a paired t test fails to show a consistent trend then this "occasional" mis-classification is not important when studying whole communities since some malnourished children will be classified as "normals" and perhaps the same number of normals as malnourished. Nevertheless the paired t test in theory is unsuitable in nutritional terms since equal emphasis is given to a 100 gm. difference at a height of 60 cm. as to a 100 gm. difference at a 120 cm. However at the 120 cm. height value a 100 gm. deficit would be nutritionally much less important than in a child of 60 cm.

Several conclusions may then be drawn:

1. The Monograph tables for weight for height for pre-school children are not statistically correct and at certain heights they may be appreciably in error.

2. The Van Wieringen method is a much more appropriate and sound method of calculating weights for heights. This method requires, however, that there should be large numbers of children in the standard group and that a much more rigorious analysis is undertaken.

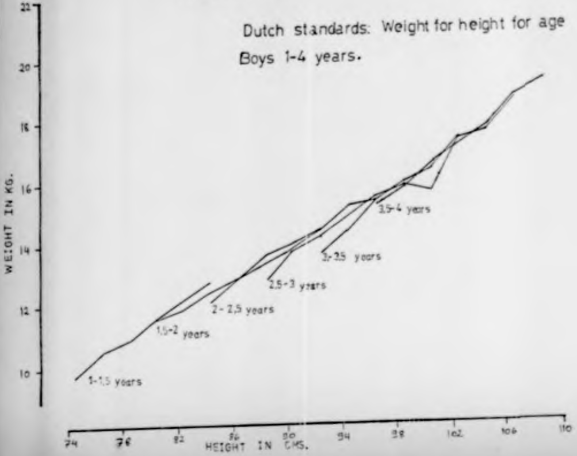
3. The assumption that weight for height is totally age independent may need rethinking since this assumption may be in part, an explanation for some of the discrepancies between the Jelliffe and the Van Wieringen methods. We therefore decided to analyse the Dutch data further to see whether age had an effect on weight for height.

C. The Dutch Weight For Height Standard For 1 - 4 Year Old Children:

Figure III. 41. gives the heights on the Y axis in 1 cm. intervals. Weight is given in 1 kg. intervals on the X axis. Weight for heights is arranged for age which is grouped in half yearly intervals.

According to this graph, which is the best visual method of showing the weight-height relationship, children in almost every age group below 3.5 years, who are short for their age are also unusually thin, i.e. they have a much lower weight than younger children of the same height. It is interesting that this difference becomes less apparent in the older children when their rates of growth are slower. It does raise the possibility that in the Netherlands with its generally well nourished population there may be groups of children whose height is being limited by the same factors which lead to the limitation in weight. Alternatively, it may be that those children who are genetically shorter tend also to be genetically thinner. If this was so, one would perhaps expect the differences to be maintained throughout the growth period but by the age of 3.5 and 4 (the last groups shown on the graph) this difference is not apparent.

FIGURE III. 41.



Newens and Goldstein (1972) reported that their arbitrarily chosen weight for height index which was independent of height was capable of distinguishing children who were short but fat. This analysis claimed that short children could be fat for their height. But in this, they were dealing with only one age group ---7 year olds from the National Development Study and did not take age effects into account.

On a priori grounds if age affects body composition independently of height in the younger age groups ---that is in a manner similar to that expected in puberty --- then perhaps with muscular development and bone growth we might expect children to be heavier at a particular height if they were short for their age. This presupposes that those factors, often nutritional, which affect height would not also affect "development"; this may not of course be true.

Therefore we believe that the Dutch data illustrates the need for caution when critically evaluating the weight and height measurements of children in a community.

This analysis has dealt with children over the age of one ; as we shall see there is a considerable controversy about the importance of age independent weight for height standards for infants.

D. The Comparison of Weight For Height Standards For School Children:

Our second concern was then to see whether the weight for height standards given by the Monograph (Jelliffe, 1966) were suitable for school children. The tables in this Monograph were presented for children between the ages of 6 and 19 years and were based on Baldwin-Wood Tables.

A careful examination of the Dutch data showed that there was considerable variability in weight for height during adolescence and this must be remembered when simplified tables of weights for heights are produced independently of age by methods which strictly speaking are statistically confutable. Thus a 6 year old child measuring 125.0 cm. weighs 24.3 kg. whereas a "short" 8 year old of similar height weighs 24.5 kg. Among older age groups, a 10 year old child who is 150 cm.tall weighs 38.1 kg. but a 15 year old, 150.0 cm. tall child weighs 39.2 kg. Similarly a 13 year old 160.0 tall child weighs 52.3 kg. but a 18 year old child with the same height is very much heavier at 59.0 kg. These differences between weights at similar heights at different ages show an increase with increasing age and probably relates to the developmental changes of adolescence. At this time, the growth rate is fast and very variable from one individual to another. Tanner (1962) has pointed out that the time at which the adolescent spurt begins is so variable that the distribution in terms of time of onset of puberty is roughly gaussian.

It therefore seems likely that in school children we cannot consider weight for height to be independent of age; the effect of age becomes increasingly important after the age of 10.

An inspection of Jelliffe's Monograph and indeed of Baldwin's original paper (1925) shows that it is impossible to assess properly the validity of the figures given for weight for height for age since many of them at the extreme ranges (i.e. in those areas where we have the greatest interest) are calculated values and it is not even clear to which percentile any particular weight for height corresponds. Values are only given for the median weights at each height interval for each age. Only in the Dutch analysis do we have appropriate tables for assessing weight for height distributions. This demonstrates the particular value of the Dutch work. This also means that the Baldwin-Wood tables give us no inherently useful cut-off point because the choice of a suitable value would be arbitrary.

With the Dutch data we then tried to compare the variability in weight with the variability in weight for height at each age taking as an example, the median height value for the age group. This can be analysed in terms of distribution coefficients, as shown in Table III. 25 . The distribution coefficient is calculated from $\frac{1}{2}(P_{90} - P_{10}) / P_{50} \times 100$ where P refers to the corresponding percentile. The calculated value measures the dispersion of values in percentile units and relates to the spread of values to the absolute mean figure; and this approach originally used by Van Wieringen corresponds closely to the coefficient of variation. During both pre and post adolescence the coefficient for height remained fairly constant at 5 %. On the other hand, at all ages, the coefficient for weight was about three or four times more than for height, that is 15 - 20 %. These two indices used in weight for height values were included in an assessment of weight for height data from the Dutch data to see to what extent the variability in weight within an age group could be accounted for by genuine differences in weight for height.

Table III.25 shows that a considerable degree of variability in weight can be ascribed to differences

Table III. 25.

The Coefficient of Distribution for Weight For Age and Height For Age. Derived from Dutch Standards.

Age Groups in Years	Coefficient of Distribution	
	Height For Age	Weight for Age
0 - 1	3.4	14.0
1 - 2	4.2	17.4
2 - 3	4.4	16.0
3 - 4	4.5	16.4
4 - 5	4.8	1[illegible].8
5 - 6	4.9	17.9
6 - 7	5.1	19.9
7 - 8	5.2	21.5
8 - 9	5.1	22.5
9 -10	5.0	23.5
10 -11	5.0	23.5
11 -12	5.0	24.2
12 -13	6.0	24.6
13 -14	6.3	25.0

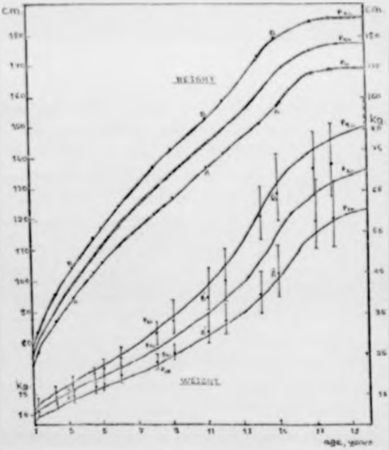
in height so that within a "normal" population variability in weight can only be a very approximate indication of altered body composition. This is well recognized in adult anthropometry for example in the construction of Metropolitan Life Insurance Tables, but this has received much less attention in children. Van Wieringen has shown this in his Monograph. Figure III. 42. is redrawn from his Graph 8.12 to show the extent to which height can alter the interpretation of weight for age data.

We have however compared the Baldwin-Wood tables with the Dutch standards to see whether there are any observed differences in weight for height which might reflect either a secular change in growth or genetic differences. Both groups are of rather similar racial origin and represent "healthy" populations so that genetic differences are unlikely. A comparison is also made with Scott's data from London School children measured in 1959 (Table III. 26.).

We know that there have been secular increases in body height and weight between the time of collecting the Baldwin-Wood figures and the Dutch standards. It was important therefore to decide whether there were marked differences between the standards because if so then despite the statistical superiority of the Netherlands data we would need to reconsider their

Figure III.42

Median (P_{50}), P_{10} and P_{90} of weight-height-age for specified P_{10} and P_{90} values of attained height, plotted in a diagram of attained weight. (Boys 1.0-20.0 years of age)



J.C. Van Wieringen. "Secular changes of growth", 1964-1966. Height & weight surveys in the Netherlands, Leiden, 1972
[illegible]

Table III.16.

A Comparison of Mean Weight For Mean Height and Mean Weight For Height At Each Age: Baldwin-Wood, Dutch and Scott Tables

Ages in Years	Dutch Tables			Baldwin-Wood Tables		Scott Tables	
	Height/Age (cm)	Weight/	Weight/Ht Age (kg.)	Height/Age (cm.)	Weight/Ht. Age (kg.)	Height/Age Range (cm.)	Weight/Ht. Age (kg.)
6	117.8	21.2	21.2	118.0	21.5	115.0-119.9	21.7
7	123.8	23.6	23.6	124.0	23.9	120.0-124.9	[illegible]
8	129.6	26.2	25.8	129.0	26.5	125.0-129.9	25.9
9	134.8	28.8	29.0	134.0	[illegible]	130.0-134.9	28.1
10	139.8	31.4	30.8	140.0	32.2	135.0-139.9	31.0
11	144.6	34.5	34.9	145.0	35.4	140.0-144.9	34.1
12	149.6	37.9	37.3	150.0	39.0	145.0-149.9	37.4
13	155.1	42.2	41.2	155.0	42.7	155.0-159.9	45.2
14	161.3	47.8	47.6	161.0	48.1	160.0-164.0	49.8
15	168.6	54.6	54.4	169.0	55.7	165.0-169.0	53.3

use if we became conscious for example that an appreciable number of the Dutch children were obese. This would then affect our choice of standard for comparing with Montserrat and other developing countries.

The compilation of Table III.26 was difficult because it became apparent that the Scott data were classified into such broad height intervals that a height on the borderline between one group and another would seriously be affected if the upper weight rather than the lower weight were chosen. This did not prove such a problem with the Baldwin-Wood Tables which in general showed equidistant values to those from the Netherlands. Therefore it would seem on this basis that the Dutch weight for height tables would be used in preference to the Baldwin-Wood data because the overall values were equivalent and the additional values of weight-height distributions could then be obtained.

We may conclude that several of the underlying assumptions used to derive currently used standards for weight for height may be questioned. It is not clear, however, at this stage whether the differences between standards affect the interpretation of results or indeed whether the additional emphasis laid on the analysis of the Netherlands surveys is necessary. For this we need to examine the Montserrat data once more.

E. The Weight For Height Analysis of Montserrat Pre-school children:

For this analysis frequency distributions of weights for each 2 cm. of height was prepared and the mean weight for each height was then calculated (Table III. 27).

In Figure III. 45 the mean weight for height of Montserrat pre-school children were compared with the standards for pre-school children which are derived by Jelliffe (1966) and a modification of the Dutch standards. The adjustment of the Dutch data had to be made because no evaluation was made where weights for height are calculated independently of age. In an attempt to make the Dutch data comparable for present purposes we therefore took a mean of the weights at different ages for a given height.

In our group, there were 5 children who were approximately 15 days old and were found to be very short, i.e. between 42 and 49 cm. Children between 50-74 cm. appeared to be rather overweight for their length but the taller children tend to have weights closer to the standards. By 75 cm. there was a marked dip in the curve showing that above this length Montserrat children had changed from being heavy for their height to being lighter for their heights. A similar but less marked effect was seen when the Harvard data was compared with the Dutch.

Table III. 27.

The frequency distribution of weights of Montserrat for each height interval. Comparison with Jolliffe and Dutch tables.

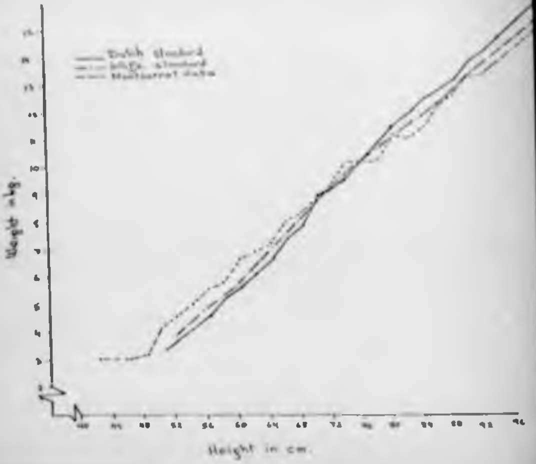
Height interval in cm.	Montserrat Mean weight in kg.	No.	SD. of weight in kg.	Jolliffe weight in kg.	Dutch weight in kg.
42 - 43	3.00	1			
44 - 45					
46 - 47	3.00	2			
48 - 49	3.22	1			
50 - 51	4.27	5	0.70		3.32
52 - 53	4.51	8	0.48	3.90	3.72
54 - 55	5.00	13	0.69	4.45	4.[illegible]4
56 - 57	5.54	8	0.77	4.90	4.62
58 - 59	5.73	19	0.86	5.35	5.31
60 - 61	6.63	15	0.82	5.85	5.68
62 - 63	6.99	13	0.92	6.45	6.[illegible]5
64 - 65	7.21	25	0.73	7.05	6.68
66 - 67	8.09	27	0.96	7.65	7.44
68 - 69	8.32	28	0.83	8.25	7.86
70 - 71	8.83	31	1.13	8.85	8.92
72 - 73	9.41	41	0.80	9.35	9.23
74 - 75	10.11	41	1.13	9.80	9.38
76 - 77	10.08	48	1.06	10.30	10.40
78 - 79	10.17	29	0.80	10.70	10.92
80 - 81	11.20	38	1.14	11.10	11.70

Table III. 27. continued.

Height interval in cm.	Montserrat mean weight in kg.	No.	SD. of weight in kg.	Jelliffe weight in kg.	Dutch weight in kg.
82 - 83	11.12	35	1.18	11.50	11.90
84 - 85	11.46	24	0.89	11.90	12.50
86 - 87	12.28	37	0.96	12.30	12.80
88 - 89	12.57	34	1.07	12.70	13.10
90 - 91	13.29	38	1.00	13.25	13.90
92 - 93	13.38	48	1.03	13.70	14.20
94 - 95	13.85	48	1.27	14.15	14.70
96 - 97	14.39	61	1.47	14.60	15.30
98 - 99	14.85	62	1.10	15.15	15.80
100-101	15.60	63	1.64	15.70	16.1
102-103	16.08	57	1.20	16.25	17.20
104-105	16.39	38	1.43	16.85	17.50
106-107	17.20	37	[illegible]	17.45	18.60
108-109	18.00	24	0.99	18.00	19.10

FIGURE III.49.

Comparison of weight for height relationship of Montserrat pre-school children with Dutch and Harvard Standards



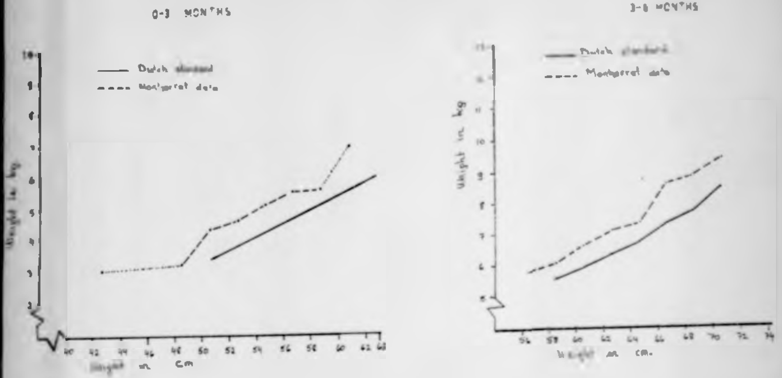
To see whether the approximations used in calculating overall mean weights for heights as well as the age effects were important, the data for the infants were compared with the Dutch standards those now being used in their original form, weight for height for age tables. The weight for height for age values were plotted for the 3 monthly age groups under 1 year of age and in larger age intervals for older age groups. Figure III.44 shows the comparison of Montserrat weight for height for age values with the Dutch standards. It is quite clear that the overall conclusions remain the same. Infants are on average "overweight" until after 6 months of age when a relative decrease in weight for height becomes obvious. Although Dutch children are known to be much taller than their counterparts in other Western countries this weight for height for age comparison shows very clearly that Montserrat pre-school children were found to be much shorter for their age than standards representing average "healthy" populations.

These tables and Figures refer only to mean values when in a community we need to have some indication of the scatter of results about the mean and in particular the numbers of children who are definitely below an appropriate weight for height.

Figure III.44.

THE COMPARISON OF MONTSERRAT WEIGHT FOR HEIGHT

FOR AGE VALUES WITH THE DUTCH STANDARDS



9–12 MONTHS

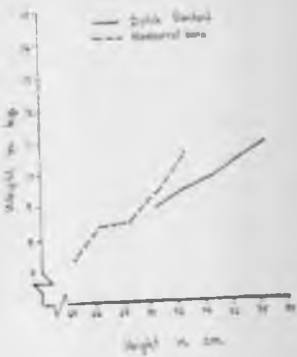


Figure III.44. continued.

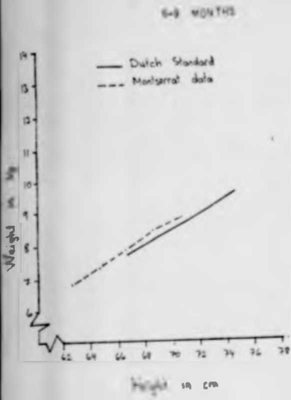
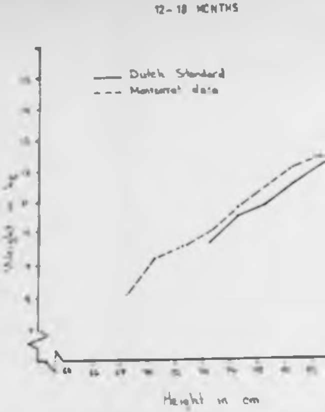
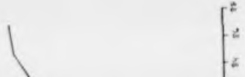


Figure III 44 continued.





III. 5. PERCENTILES:

When weight, height and weight for height are considered together as indices of body proportions, the inter-relationship between the three is thought to be important in detecting marginal nutritional deficiency. However, weight, height and weight for height are in different units of measurement and it would be helpful if we could develop an analytical system which would give equal emphasis to a weight or a height change.

Strictly speaking our data cannot be handled as if they are longitudinal but the data may allow a greater capacity for interpretation if we can think in terms of changes in anthropometric measurements with age. On this basis we could then begin to understand the sequence of events during growth and this may be informative in terms of retardation in either weight or height or both. It is possible that retardation in height only follows changes in weight or vice versa. In an attempt to put weight, height and weight for height on a comparable scale we decided on the following system. This system involves the transfer of all three parameters for individual children or mean values for groups to percentile units for each measurement. It was also hoped that this method would in the future provide a more precise way of evaluating longitudinal data.

As described earlier, metric units were employed and the measurements were analysed as the mean or median values for specific ages as well as percentages of the standard. Weight for height could only be calculated as the percentage of the standard. By changing the units into percentiles it became possible to show the changes as well as the differences of each index both for an individual child and for a group of children of the same age on the same scale.

A. Derivation of Percentile Method

Before explaining the derivation of percentile figures, a brief description of the terminology used along with the basic procedures involved in tabulating the scales and the standards used for this purpose will be given.

In anthropometry "percentiles" are very frequently used as a measure of a frequency distribution; thus there are 99 percentiles which divide the distribution into 100 equal parts. Just as the median characterises a series of values by virtue of its midway position, percentiles show either the location of a value within that distribution or refer to the part of the distribution in which an item falls. The percentiles are particularly useful as a measure of dispersion or skewness and are preferred with the median value in anthropometry because the distributions of anthropometric measurements are usually asymmetrical. Table III.28 summarises the standards chosen for percentile expression.

Table III.28.

The standards used in the derivation of percentile values for pre-school and school children

Measurement	Weight	Height	Weight for Height
Age Group			
Pre-school	Harvard St.	Harvard St.	Dutch St.
School	Harvard St. Dutch St.	Harvard St. Dutch St.	Dutch St.

The Harvard standards for weight and height were used as the standard scale for converting the actual weight and height values into percentiles. These standards were already presented as values in percentile groups for each group. For the ages between 0 months and 2 years the weight and height values were given in 7 percentile groups, that is the 3rd, 10th, 25th, 50th (the median), 75th, 90th and 97th percentiles. However for those grouped into half yearly age intervals for example, for children aged 2.5 years or 3.5 years, only 5 percentile grouping were given, the 3rd and 97th measurements are usually asymmetrical. Table III.28 summarises the standards chosen for percentile expression.

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The problems involved in choosing the most suitable weight for height standards remained and has been discussed in the previous section. We decided that the weight for height for age standard given by Van Wieringen (1972)for Dutch children would be appropriate since it represents a large sample which has been analysed in a correct statistical manner. The only disadvantage is that they are presented in 3 percentile groups only. The values corresponding to the 10th 50th and 90th percentiles for each 3 monthly age groups up to 15th month were tabulated and thereafter ages were classified at 6 monthly intervals up to 4 years of age. The age grouping was made in 1 yearly intervals for children between 4 and 13 years of age. For each age group values corresponding to 3rd and 97th percentiles were excluded.

The Method by Which The Standard Cumulative Frequency Curves Were Obtained:

The anthropometric variables were plotted on an arithmetic graph paper. The X axis was taken for the variable and the Y axis represents the percentile distribution. For example, for the 3 months age group, the 3rd, 10th, 25th, 50th, 75th, 90th and 97th percen- tile height values for males are given as 56.7, 57.8, 59.3, 60.4, 61.8, 62.8 and 63.7 cm. respectively. When these points are joined together we obtain a "S" shaped or sigmoid cumulative frequency curve for that age as shown in Figure III. 45 . In the height for age curves the height values were arranged in 1 cm. intervals on the X axis. The type of the curve is sigmoid for almost every age group but as the age increases the slope of the curve changes and reflects the wider distribution of height values. In the weight for age curves weight values were given in 1 kg. inter- vals on the X axis. An example is given in Figure III. 46.

For the weight for height graphs, we chose the X axis as the weight scale where the weight is plotted in 1 kg. intervals and the curves obtained represent height in 2 cm. intervals. The graph is plotted on a large scale to avoid an overlap of curves. The values for each three monthly age group were drawn on one graph, for example, as it is shown in Figure III. 47 . Solid and dotted lines represent the weight for height for age distribution during the first three months of life for boys and girls respectively. These curves have linear characteristics because there is an almost linear relationship between height and weight. Extreme values corresponding to 3rd and 97th percentiles could not be plotted.

The conversion of the actual weight, height or weight for height values into percentiles was then made possible by interpolation. Thus the percentile value, for example for height, for a given age, sex group or an individual child was read from the standard cumulative curve prepared for that variable at that sex and age. Thus a male child of 3 months of age whose height was 59.5 cm. and weight 5.5 kg. was found to be on the 30th percentile for height, 35th percentile for weight and on 40th percentile for weight for height. This method of interpolation has proved to be very easy once the standard cumulative curves as scales are provided. This shows itself especially in the case of weight for height because every curve representing height in 2 cm. intervals are plotted on one graph paper for 3 monthly intervals.

It must be emphasized that the weight for height scales taken from the Dutch standards are selected in terms of age too. In other words the scales are not merely a weight for height scale produced from data on all children irrespective of their age. If a child is 3 years old and short then the percentile scale is different from that which would be applied to a child of similar height but 2 years 9 months old. In fact this age dependent change in body proportions is vividly demonstrated by choosing percentiles which therefore appear to be an extraordinarily sensitive method of looking at body proportions. For example a boy, 92 cm. tall and weighing 14 kg. would be on the 42nd percentile if he were 2.5 to 3 years old but on the 62nd percentile if he were 3 to 3.5 years old. This difference reflects the normal change in body proportions during normal growth in the standard children who become "lighter" as they grow. These changes although apparently small are consistent and it would appear from the present analysis that this fact must be taken into account in analysing weight for height data.

When the standard cumulative curves of pre-school age group for both sexes are examined carefully, the differences between the curves for males and females reflects the expected differences; girls being shorter and lighter than boys at the same age. The difference between the 2 sexes for weight for height for age are shown in Figures III.45., III.46., III.47.

Although these curves are potentially applicable to any data both longitudinal and cross sectional we finally decided not to include them in this thesis particularly when it is clear that the Dutch data could be used for percentile derivation by a computer. For the analysis of this work however a manual graphical method was employed.

Figure III.45.

STANDARD HEIGHT FOR AGE PERCENTILE GRAPHS FOR BOYS AND GIRLS DERIVED FROM DUTCH DATA

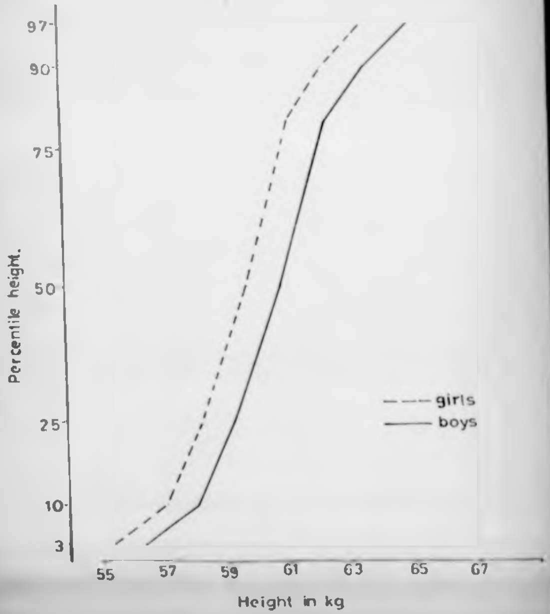


Figure III.45 continued.

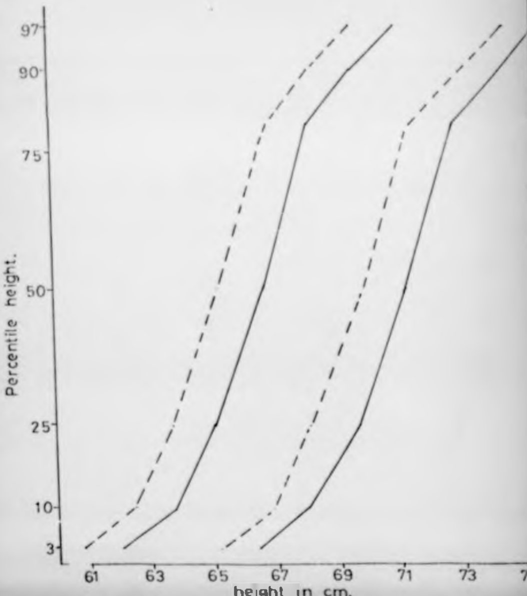


Figure III.46.

STANDARD WEIGHT FOR AGE PERCENTILE GRAPHS

FOR BOYS AND GIRLS DERIVED FROM DUTCH DATA

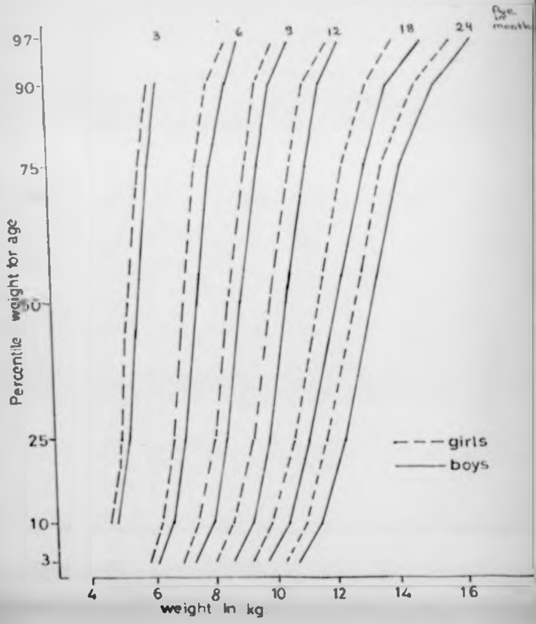


Figure III.46 continued.

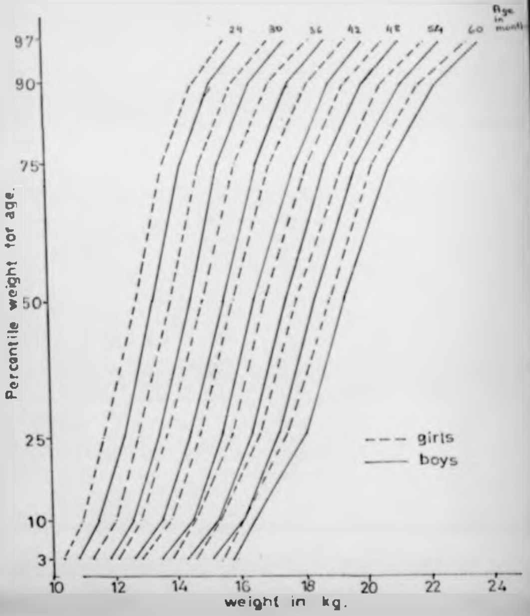
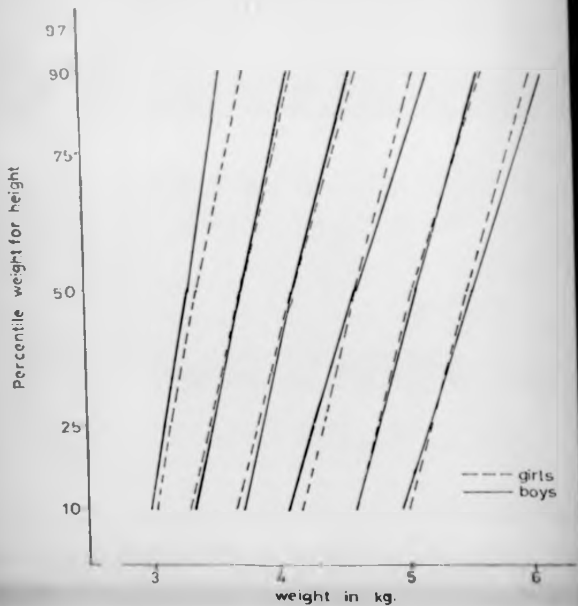


Figure III.47

STANDARD WEIGHT FOR HEIGHT FOR AGE PERCENTILE GRAPHS FOR BOYS AND GIRLS DERIVED FROM DUTCH DATA



b. Analysis of Montserrat Results As Percentiles:

For our initial analysis, Montserrat children were grouped into 3 monthly age intervals for the first 18 months of life then in 6 monthly intervals up to 60 months. The median anthropometric values of school children were calculated in yearly age groups. For the percentile calculation a slight modification in age grouping had to be made. We realized that our previously tabulated values for median weight for height in, for example the 0 - 3 months age group could not be compared with the Harvard standard values which are given specifically for children 3 months old. If we had Harvard standards prepared for each monthly interval with percentile distributions this would not cause difficulty but a problem developed over the choice of a suitable standard for the real age of the child. This of course is related only to the comparison of weight or length with Harvard standards and not to the weight for height Dutch standards which were given not for specific ages but for age intervals. The reasons for the different expression are a reflection of the difference between the Harvard and Dutch standards. The Harvard standards were derived longitudinally and would be specific for a definite age with all the children measured for example at 3 years of age. The Dutch data, which is cross sectional, had to rely on age interval grouping.

Therefore we had to relate Montserrat data to the standards by comparing with two different standards. For the Harvard comparison there were difficulties particularly in the data for children below 1 year of age. In order to find the median height or weight at 3 months, children between the ages of 2, 3 and 4 months old were grouped together. It was quite clear that we would not be able to include children who were 1 month old or less because the median values for this age group could neither be compared with the 0 months nor with the 3 months value on the percentile scale. Apart from the exclusion of this small group all other children could be included by grouping them around the standard. Thus children from 2 years 9 months old to 3 years 3 months of age were compared with the 3 year old Harvard standards.

Tables III. 25 and III. 30 give the median height, weight with percentile height, weight and weight for height for age values of pre-school children for boys and girls separately. The median weight for children in the 3 months old group were found to be on the 76th and 62nd percentiles for boys and girls respectively Although these children seemed to put on weight very well their heights fell from the 35th to the 25th percentile below the standard 50th percentile value, weight for height for age was naturally above the 97th percentile. After the first few months of life the children's

Table III. 29.

Median height and weight for age with percentiles for height, weight and weight for height of pre-school boys in Montserrat. The comparisons were made with Dutch and Harvard standards.

Age Groups in months	Median Wt. in kg.	Percentile weight		Median Ht. in cm.	Percentile height		Percentile wt. for ht.
		H.	D		H	D	D
3	6.10	76	75	59.4	35	25	100
6	7.60	51	50	64.9	22	11	97
9	8.50	26	25	70.0	28	18	45
12	9.50	25	17	72.7	14	6	55
15	10.00	22		74.7	5		57
18	10.20	10	8	77.0	0	0	40
24	11.20	10	7	84.0	8	7	14
30	12.60	32	11	88.6	11	9	27
36	14.10	35	19	93.7	23	16	46
42	15.10	37	19	96.5	15	10	45
48	15.20	23	9	100.4	21	13	15
54	16.40	31	15	104.1	26	17	28
60	17.70	22	22	107.4	21	18	48

D = Dutch standards

H = Harvard standards

Table III. 30.

Median height and weight for age with percentiles for weight, height and weight for height of pre-school girls in Montserrat. The comparisons were made with Dutch and Harvard standards.

Age Groups in months	Median Wt. in kg.	Percentile weight		Median Ht. in cm.	Percentile height		Percentile wt. for ht.
		H	D		H	D	D
3	5.80	62	67	58.0	26	20	100
6	7.25	50	52	64.1	31	17	76
9	8.30	35	35	67.7	18	9	63
12	8.75	18	15	71.6	18	6	30
15	9.80	28		76.0	30		31
18	10.45	30	20	77.3	13	4	54
24	11.20	20	14	82.3	12	6	38
30	12.70	32	25	89.3	25	21	38
36	13.40	25	20	93.4	25	21	38
42	14.10	22	16	97.2	20	21	27
48	15.15	23	17	100.2	24	17	35
54	16.25	29	21	104.7	33	25	33
60	17.40	24	25	108.2	35	24	26

D = Dutch standards

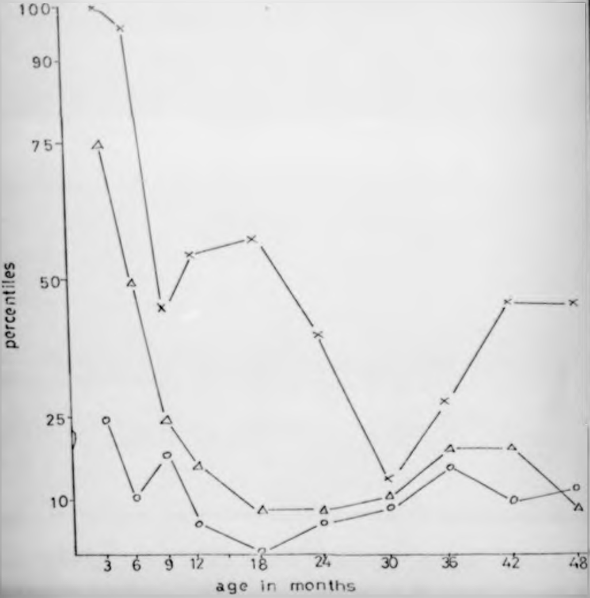
H = Harvard standards

growth had slowed down and the median height percentile fell progressively until it was estimated to be 0 at 18th months. There was in addition, despite the increase in absolute weight, a marked fall in the children's weight for height for age so that by 18th month of age this percentile had fallen below the standard. This reduction below the 50th percentile seemed surprising because the percentile weight was always above the percentile height. According to our scheme the weight for height values should accurately reflect the disparity between the weight percentile and the height percentile. In Table III.29 the 48 months old boys had a percentile weight value of 23 and a height percentile of 21. Their weight for height percentile should therefore be above 50 and not 15 !.. It then became clear that differences between standards, which traditionally are considered to be small, may in fact be very important when values are expressed in percentile terms. The wish to maintain comparisons with Harvard standards had led us to use these for weight and for height although it was not possible to derive mathematically appropriate weight for height values from them as explained in Section III.

The comparison of Harvard and Dutch standards showed that the Dutch pre-school children were both taller and

Figure III 48.

THE WEIGHTS HEIGHTS AND WEIGHT FOR HEIGHTS OF MONTSERRAT PRE-SCHOOL BOYS EXPRESSED AS PERCENTILES



heavier so this might be a cause of the discrepancies if the Harvard and Dutch children had a different weight for height.

Two things then became apparent from this work: first, there was a need to assess the difference between standards using our percentile method as a means for showing small changes between them and as a method for obtaining some information on relative weight for height values. Secondly there appeared to be a need to express our Montserrat data in terms of the Dutch standards since the Dutch data were analysed appropriately.

C. <u>Differences Between Available Standards From Europe and the United States:</u>

Figures III.49 and III.50 show the height and weight percentiles of 5 "standard groups of children based on the Harvard standards. Three London surveys are included from data collected in 1912, 1938 and 1959. These three curves for London children show very effectively the progressive secular increase in weight and height of children over the years.

The American data are particularly interesting because it would appear that the Harvard standards represent the maximum height which children of Caucasian stock are likely to attain at this age since there are few differences between the 1970 America data

(Barr, Allen and Shinefield; 1972) and those from the Harvard data collected in the 1930's. The only marked change at the age of 12 probably represents the earlier pubertal spurt of children in the 1960's.

The Dutch data show very similar height values but the weights of Dutch children are clearly less than those of American children in the 1930s. American children's weight in the 1960's has moved up 20 percentile points however and clearly they would have greater weight for height values. The comparison of the two Figures shows that if weight for height data from Harvard were obtainable then it is likely that the Harvard school children had a greater weight for height than the Dutch children, data collected 20-25 years later.

Thus the effect of using Dutch standards would be to alter the weight for height relationship in particular.

The figures also show the position of the Montserrat school children in relation to that of the other groups. In the early years at school Montserrat children seem to have a median weight which approximates to the 25th percentile, whereas the height percentile varies about the 30th percentile line. This variability probably reflects the small size of our group compared with the standard values. The data suggests however that since the weight percentile is below the height percentile then the children on average would be thinner as well as be more stunted than the standard values. Since, however, there is no means of [illegible] this accurately without relating the weight for height to [illegible] data, we must [illegible] that the Dutch school children as inferred from Figures III.4[illegible] and III.[illegible] are in fact "thinner" than Harvard group. Thus the Montserrat school children would be classified as on average "thinner" than Harvard standards but "fatter" than Dutch children despite their being stunted compared with both standard groups. This is illustrated in Figure III.48. which shows the weight for height percentiles of boys when compared with the Dutch data.

A further analysis was then undertaken to see whether the percentile method was appropriate for longitudinal data.

FIGURE III. 49.

WEIGHT PERCENTILES OF BOYS FROM DIFFERENT COUNTRIES COMPARED WITH HARVARD STANDARDS

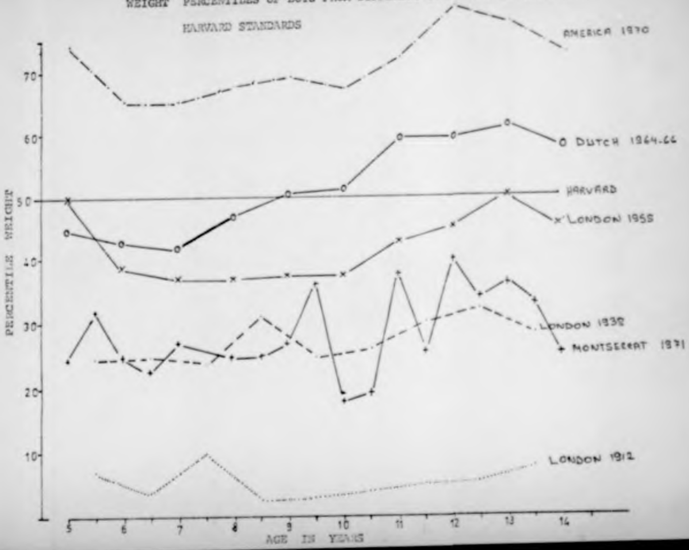
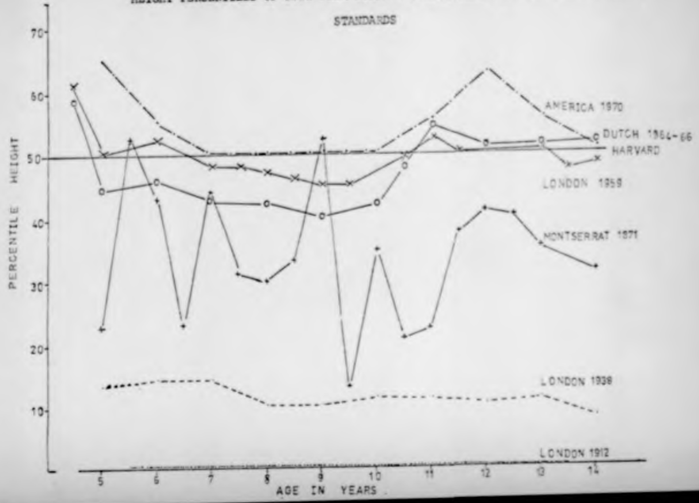


FIGURE III. 50.

HEIGHT PERCENTILES OF BOYS FROM DIFFERENT COUNTRIES COMPARED WITH HARVARD STANDARDS



D. Analysis Of Longitudinal Data By Percentile Method:

The percentile method was thought to be most useful in the assessment of nutritional status of an individual child if the measurements are collected longitudinally at various age intervals. To assess this point we have converted the height and weight for age values of a Turkish child who was measured by a single observer longitudinally over a period of 60 months.

Figures III.51 & 52 shows the comparison of the height and weight growth curves of the Turkish child measured at intervals from birth with the Harvard Standards in the traditional way. The growth pattern is typical of many children in developing countries. At 18 months of age the weight of this child falls below the 3rd percentile and would therefore be classified as malnourished by any standard method which considers the weight for age as the most important indicator of malnutrition. The height curve however also shows a decline which occurs much earlier, at 9 months of age. This faltering then raises the question of whether the slow weight gain merely reflected a failure in growth or a genuine change in the body proportions. By converting the absolute values into percentiles, the height and weight for age changes have been expressed in the same units so that the influence of height gain on weight changes can be assessed directly.

The child's height and weight in percentiles was found for the whole period of study. In Figure III.54. a similar weight for height for age in percentiles was shown in addition to the weight and height percentile curves. It is clearly demonstrated by this graph that although the height falls below the 3rd percentile at 12 months and weight at 18 months the weight for height for age does not fall below the medium weight for height for age value. Body proportions as a whole does not show a great change. The child is small for his age but is not wasted.

FIGURE III. 51.

THE COMPARISON OF THE HEIGHT CURVE OF A TURKISH BOY WITH THE HARVARD STANDARDS

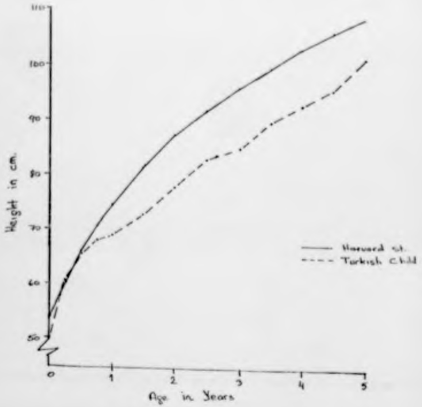


FIGURE III, 52.

THE COMPARISON OF THE WEIGHT CURVE OF A TURKISH BOY WITH THE HARVARD STANDARD

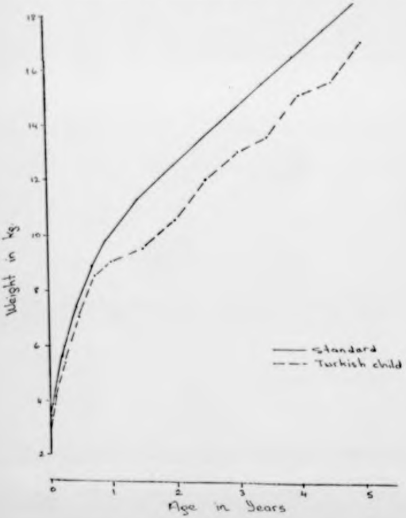


FIGURE III.53.

THE COMPARISON OF THE WEIGHT FOR HEIGHT CURVE OF A TURKISH BOY WITH THE WEIGHT FOR HEIGHT STANDARD

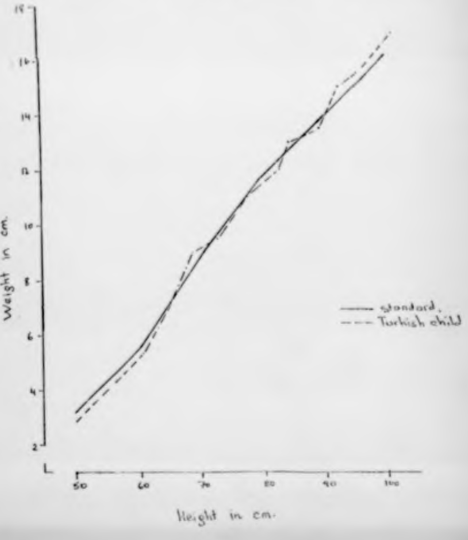
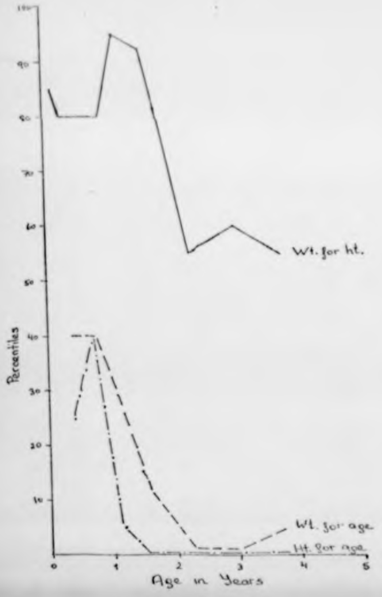


FIGURE III. 54.

THE ATTAINED WEIGHT? HEIGHT AND WEIGHT FOR HEIGHT VALUES OF THE TURKISH BOY EXPRESSED AS PERCENTILES.



Conclusion:

The percentile conversion technique is in fact another way of comparing the weight, height and weight for height for age values with the standards. By converting the actual values of these parameters into percentile units, we are obtaining a percentile related distribution and showing the position of the actual values in relation to the standard used. The characteristics of the technique can be summarised as follows:

1. Visual demonstration of the nutritional state of children over a complete age range on one graph.

2. All parameters are expressed in equivalent units.

3. It allows the demonstration of possible inter-relationships without the need to analyse each one separately and then attempting to relate weight and height and weight for height in an abstract form.

4. In particular it can be used in illustrating the type of malnutrition for individuals or groups of children. For example, the analysis of Montserrat pre-school group revealed the fact that during infancy there was a tendency towards "obesity" between the ages of 0 month and 3 months. The degree to which shortness of height affected the interpretation of the weight values became clear with this analysis.

5. It is a sensitive method of demonstrating a "change" in the nutritional status of an age group or an individual.

However the question we should answer is whether this technique is a useful method for analysing anthropometric results. It is important to point out that we are still limited with this technique because we are analysing cross sectional data where the median values were obtained from different groups of children. Curves constructed from the values of different children in each age group do not necessarily reflect changes in body composition with growth in individual children.

Percentile expression seems ideal in analysing longitudinal data. Even the smallest change in body proportions of an individual child or a group of children can be demonstrated and it seems to be a suitable format for illustrating the mild degrees malnutrition. Sensitivity of this method of expression depends however on

a) an accurate assessment of age, because changes over time are observed and

b) on accurate measurements.

A slight error in the collection of the measurements might give very different percentile values.

One might well ask whether this method of expression has any advantages over the currently employed percentage values. We believe that it does for the following two reasons.

1. It is more meaningful in nutritional and anthropometric terms because a percentile implies the degree to which

a child is stunted or underweight or even obese for his age group. For example, the expression "the child's weight is below 3rd percentile means that the child under consideration is remarkably underweight. On the other hand, the expression "the child's weight is 80 % of the standard" requires more explanation. The term percentile is also more commonly used in explaining the characteristics of the distributions of parameters such as weight and height.

2. It does allow an immediate and relevant comparison of measurements because they are given by the same units and again become more meaningful in nutritional terms.

The disadvantages of the method is that since it is so sensitive a method of expression, we require better standards based on values for smaller age intervals. For example, in the analysis of Montserrat data we had to rearrange the age groups to obtain relevant median values comparable to the standards.

In addition although this method seems very easy to apply it does involve the preparation of standard graphs (approximately 50 in all) and interpolation for percentile values would be much more tedious than merely obtaining a percentage value. A worker in the field is unlikely to use this technique but those with access to a computer could find it helpful in analysing their data.

All these conclusions presuppose that measurements can be made so accurately that meaningful changes in weight or height can be discussed with confidence.

On reaching this conclusion it was necessary to investigate the accuracy of measurements of anthropometric data to see whether this would influence our results or their interpretation.

III. 6. THE ACCURACY STUDY

Our preliminary analysis of the height and weight results revealed the fact that in general there were many children between the ages of 0 months and 2 years who were short for their age. These same results were analysed by a percentile method by which even the small changes in body proportions of a child could be demonstrated on the same scale. Percentile analysis also confirmed the fact that the changes in height for age were more dramatic than weight for age and the pattern which has emerged has suggested that some children were even overweight for their height and age.

The fact that children in Montserrat were short and this was as a part of our analysis then raised the question of whether the height and length measurements taken by simple instruments used in the Montserrat survey were accurate enough.

It was decided to test the simple height and length instruments and methods used in Montserrat by comparing them with more elaborate and standardised apparatus where possible. During the preparation stages of the Montserrat survey, despite our efforts we have failed to find a suitable commercial instrument to measure height and or length with a known degree of accuracy. Two small studies were carried out to clarify the questions raised by the analysis of the data. The first study took place in Northampton and the second was carried out in 2 different London nurseries.

The problem was also to assess how elaborate these methods used need to be in order to achieve an acceptable definition of nutritional state with accurate and reproducible results.

Information on the accuracy and the reproducibility of anthropometric measurements in other surveys is rather limited; in the majority of surveys where nutritional anthropometry is used these factors have been completely neglected.

A. Sources Of Error Affecting The Accuracy And The Reproducibility Of Measurements:

Here, we will summarise the available information about the sources of error, particularly on height and length measurements.

1. Differences between supine length and recumbent height:

As early as 1935, Palmer and Reed(1935) suggested that there was a 1 cm. difference between the height and length of young boys and derived equations for supine and erect length separately. Tanner (1966) also showed that at the age of 2 years the supine length is approximately 1 cm. more than the standing height.

Hamill et. al. (1972) in their conduct of a 10 State National Health Survey measured the height of subjects at successive half hour intervals during the day. The exact time of each examination was recorded so that possible diurnal or sequential effects could be analysed. Strictland et. al. (1972) also measured the diurnal variation in children's height. They observed that the height measured in the evening was less than in the morning and that the height differences was already established after 2 hours in the upright position. According to these observers a diurnal variation in height can amount to 2.5 cm. The mean difference between the morning and evening height was found to be 1.54 + 0.04 cm. and in all cases this difference was statistically significant.

It was suggested by Hamill et. al. that the recumbent position increased height presumably by relieving gravitational compression. The inter-vertebral space changes amounted to 2 cm. between supine length and standing height.

Tanner et. al.(1966) suggested a method for measuring height so that the differences due to changes in the inter-vertebral space could be minimised. By this method, the examiner applies gentle traction under the mastoid processes of the child's skull thus streching the neck and the trunk. When this technique is used in a standard manner Hamill et. al found out that an increase of 1 cm. in height could be obtained. This result is similar to Palmer's (1932) and Tanner's (1970) findings.

2. <u>Differences in height measurements due to different Observers:</u>

The occurance of differences in the measurements obtained from one person by several observers is a well known fact. It has always been suggested that a particular measurement should be taken by one observer especially in the case of longitudinal surveys.

Observer error can arise from three factors; in measuring, in reading the measurement, and in recording the observation. If an observer is not well trained it is obvious that there will be errors of measurement because he would neither know the characteristics of the instrument nor the technique for its use. Often training inexperienced observers is a comparatively simple matter but the errors in reading and recording data may still remain important. Even when the observer is highly experienced slight carelessness can result in an error. Reading and recording values do not require special skills but a great deal of attention to detail and concentration is needed.

In any survey or study, it is important to decide whether the measurement is going to be read to the nearest millimeter below or above the actual value. This provides comparable results particularly when they are taken by two different observers (Roy, [illegible], 1969). In taking measurements Tanner and Whitehouse recommend to use of two people; one to take the measurement and read it aloud and the other to record the reported measurement. The recorder hears the value and sees what is written down so that the likelihood of making errors seems to be less (Whitehouse, personal communication, 1973) but no formal proof of this has ever been published.

McDowell et. al. (1970) reported that they had used two observers to take replicate measurements and that the median absolute inter-examiner and intra-examiner differences found on replication of height measurements on the same subject amounted to only about 3 or 4 mm. They concluded that this error was unimportant for several reasons. First the differences between examiners are rarely consistent in one direction e.g. with one examiner consistently obtaining measurements less than the other examiner. Secondly the error is much smaller than the actual total value being recorded and is often very much less than the range of measurements used to classify children into groups. Thus for example McDowell et. al. grouped children into 5 cm. intervals so that an error of only 3 or 4 mm.

is unlikely to affect the grouping of many children. Thirdly, we may conclude on a preliminary basis that these errors are unlikely to make any difference to mean values for groups of children. The influence of these errors will, however be considered later.

Hamill et. al. (1970) investigated the same problem but repeated measurements after two weeks. They found that the average differences between measurements was only 3 mm. for height. They believed that this error arose from the equipment; this implies that both their observers and the children measured behaved in a perfectly standard fashion !.

3. Errors Due To Instruments:

Errors or differences in height and length measurements which are caused by the instruments themselves are usually due to bad design, wrong use or broken equipment.

Jelliffe (1966) in his Monograph suggested that a vertical measuring rod or scale, 2 meters in length and capable of measuring to an accuracy of 0.5 cm., should be used for older children and adults.

To measure height or length, a wide range of instruments from a simple tape measure to a sophisticated electronic photographic equipment are available. Hamill et. al. used a Poleroid Camera attached to the head piece on his stadiometer. This camera recorded the subjects identification number next to the pointer on the scale which gave a precise reading. Thus the permanent record of the measurement minimized observer and recording errors and in addition eliminated the problem of parallax at the reading stage. McDowell's equipment was similar.

Tanner et. al. (1969) and the IBP Handbook recommend the Harpenden's stadiometer equipped with a reader on the sliding horizontal head piece, and reading to the nearest 0.1 cm. Even the most sophisticated instrument if not functioning properly will lead to errors.

4. Differences due to methods:

Fundamentally there are two techniques recommended to be used in conjunction with the various instruments for measuring height or length. Although the basic principles are very similar for both, the technique recommended by Jelliffe (1966) is simpler and carried out by one observer. Tanner's (1969) modification was introduced to eliminate the observed differences between supine length and recumbent height due to gravitational inter-vertebral space changes. Although there is evidence that the measurements collected by this method gave greater reproducibility this must be weighed against the greater simplicity of Jelliffe's technique when the practical limitations of a field survey are taken into consideration.

Jelliffe's technique of measurement was employed in Montserrat since we were limited in staff numbers and 2 people were trained as observers one for height and the other for weight.

The work in Montserrat which has been set out so far was undertaken as already explained, with two home made instruments and with the standard Holtain Stadiometer. A real criticism of this work was that no adequate assessment of the likely errors were undertaken. During the evaluation of results, pre-school children were found to be consistently short for their age. Since almost all the children under 2 years of age were measured by either the Montserrat Height Stick or the Montserrat Length Stick it was important to establish the error due to these instruments as well as possible observer errors and to assess the degree to which the results were influenced by these errors.

The need for a study on the accuracy of our instruments led directly to two further studies one in Northampton and the other in 2 London Nurseries. The way in which these studies relate on an instrumental basis is set out in Table III.31.

Table III. 24

The Instruments Used In Accuracy Studies And In Montserrat Survey

Study Area	Age of children in years	Instruments Used To Measure Height and Length
Montserrat	0 - 14	Holtain Stadiometer Montserrat Toddler Height Stick Montserrat Infant Length Stick
Northampton	2 - 4	Holtain Stadiometer Montserrat Toddler Height Stick
Nursery Studies London	2 - 4	Holtain Infantometer Montserrat Toddler Height Stick, Microtoise, Montserrat Infant Length Stick and Length Board

h. Northampton Study:

In 1972, a year after the Montserrat survey, the Department of Human Nutrition of the London School of Hygiene and Tropical Medicine was commissioned to carry out a survey of child growth in Great Britain by DHSS. In order to measure heights and lengths of small children a special instrument was designed and manufactured by Holtain Ltd. A small scale pilot study was planned and took place in Northampton to test the methods and instruments and to find out the errors in the design of a survey which was going to be carried out on a nationwide basis.

The Northampton study seemed to be a good opportunity to evaluate our simple methods against a more sophisticated study to assess growth.

During the planning stage of the Northampton study it soon became apparent that other requirements of the study on child growth would preclude us from undertaking all the necessary tests we had already planned. For the pilot study, the observation time required to test the questionnaire and the techniques of measurement was estimated to be 30 minutes. The children to be observed had to be under 4 years of age. To find out the true differences between instruments and methods we had to repeat measurements on the same children by different methods and instruments after the observations needed for the pilot study had been completed. This unfortunately would mean many more observations on the same children who were too young to cooperate. As a result we had to decide to abandon the comparison of length measurements as well as our initial intention which was to find out the true differences between methods and instruments.

However, the results of this study could be used to reveal the differences between two different systems, i.e. the combination of methods and instruments used to assess the nutritional status of children under field conditions against the ones used to detect increments in growth and which were designed to be both sensitive to be carried out under ideal conditions.

1. Instruments used in Northampton Study:

The simple height measuring device for toddlers which was used in Montserrat survey is described in Section II.B. 4.. Here a brief description of Holtain Infantometer will be given. This instrument is designed to measure both height and length. It consists of a piece of metal platform 50 cm. in width and 150 cm. in length with a fixed foot plate and a sliding head piece which operates on miniature ball bearing rollers. This head piece is equipped with a digital reader and can slide at a slight touch of finger with a lock which stabilizes the head piece when it comes into contact with the child's head.

2. Techniques of Measurement:

In Section 11. B. 5. a description of the techniques used in the Montserrat survey was explained. The techniques recommended for growth studies by the International Biological Programme (IBP) is described below as it is necessary to point out the differences between the two methods. Although the basic principles of this technique are very similar to the ones described in the Monograph ([illegible], 1966). IBP Handbook recommends streching the body by applying a gentle traction over the mastoid processes to obtain maximal height. This modification is introduced to eliminate the natural shrinking of the body during the day. But this measuring technique requires two observers working together. While one of them is holding the child's head and applying a gentle traction under the mastoid processes the other is expected to check the child's feet to make sure that the heels are in contact with the platform in the right position and to lower the head piece to take the reading.

The field workers employed for the pilot study measured the height of the child using the Holtain Infantometer by the technique recommended by IBP (IBP Handbook, 1969). After the collection of all anthropometric measurements for the pilot study were completed, the same children were measured by myself by the Montserrat Toddler Stick 1 using the Monograph technique.

During the Northampton study measurements on 56 children out of the total of 143 were obtained. It is important to note that the comparison of the two systems i.e. IBP technique and Monograph technique was not strictly appropriate because the first set of measurements obtained by the IBP method was taken by different observers. However, the results obtained give an approximate idea about the differences between the 2 systems as well as serving as a basis for a further investigation by which the differences due to methods, observers and instruments could be analysed together.

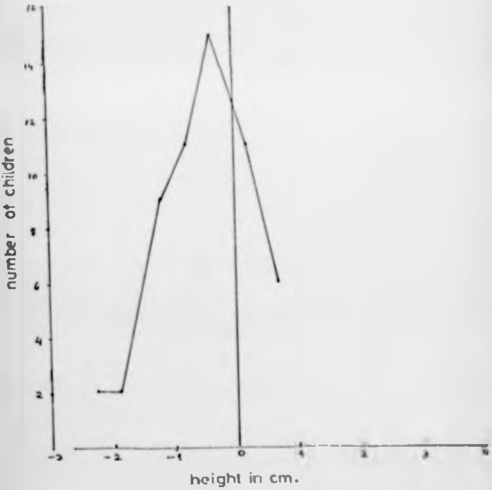
3. Results of comparison of height:

During the 10 working days, data from 56 children of the total of 143 who attended the clinics could be collected. The comparison of height measurements could be made on results obtained only from those who were very co-operative and no one was forced to agree to this extra study. Finally, 39.1% of the sample could be measured by both systems. In order to find out the differences between the two systems a paired t test was applied and the calculations were made on an Olivetti 101 Desk Computer.

Figure III 55. illustrates the results from the Northampton study with the differences between the two systems of measurements grouped to show the general trend. All differences in measurements falling for example, between -0.5 and -1.0 cm. were grouped

Figure III. 55.

THE DISTRIBUTION OF MEAN DIFFERENCES BETWEEN THE STADIOMETER AND THE MONTSERRAT TODDLER STICK, NORTHAMPTON STUDY



together and it was found in this case that 15 children fell into this category. The Figure III,55 therefore gives an indication of the general distribution of differences. This finding suggests that the Montserrat method produced results which were less than those found with the Holtain method. A more accurate analysis of the data using the paired t test was then made and indeed showed statistically significant differences ($P > 0.001$ where $t = 4.35$). In practice, 67.9 % of the measurements taken by the field system were less than the infantometer results and the range of differences was between -2.5 cm. to + 1.0 cm.

4. Discussion of the findings:

Although the differences were significant it must be remembered that various factors contributed.

a) The instruments were very different and the wooden height device is a much more simple instrument than the infantometer.

b) The techniques of measurement were different.

c) We do not know the reproducibility of the wooden instrument and this could not be tested in the Northampton study.

With these problems in mind it was quite clear that we had to differentiate between the techniques of measurement and the variability and absolute error which could arise from the instrument itself. We therefore decided to undertake a specific study which was organised in two nursery schools in London.

C. The Nursery School Study:

The main objectives of this study can be summarised as follows:

1. To find out the error due to observers, instruments and techniques in length and height measurements.

2. To find out the significance of the differences between the techniques of measurement, instruments and observers in terms of altering the results of the nutritional assessment of children in a community.

3. To assess the value of different instruments in terms cost and accuracy of a survey to assess the nutritional state of children.

The experiments which would reveal the above mentioned objectives were disqned and carried out for height and length measurements.

1. The methodology of the study was as follows:

Observers:

In both height and length experiments one of the main objectives was to find the errors or differences due to observers. Two observers, one experienced and one inexperienced but both trained were considered sufficient for a comparison to be made. Therefore

Observer I = Experienced

Observer II = Inexperienced

Techniques of measurement:

Two techniques were compared. Technique I is the method of measurement recommended by Jelliffe (1966) to field workers for the assessment of nutritional status of children (see section II.B.5). Technique II is first described by Tanner et. al. (1969) and accepted as the standard and accurate method and recommended in The International Biological Handbook (see Section

Instruments:

I. Height:

a) Holtain Infantometer

b) Microtoise: This is a very small, light, portable height measuring instrument. It was chosen because of its simplicity, commercial availability and design for field surveys to be undertaken under practical conditions. It is hung on a wall from the tape end and the container which holds the tape measure is used as the head piece.

c) Montserrat Toddler Stick I : The description of this instrument is given in Section II

II. Length:

a) Holtain Infantometer

b) Length Board: In accordance with Jelliffe's suggestion (Jelliffe, 1966) a simple length measuring device was constructed at L.S.H.T.M. Workshops. This instrument is composed of a 40 cm. wide, 100 cm. long flat board base with a fixed head piece and a sliding foot piece. A wooden ruler placed in the horizontal board base. The readings of length could be made to the nearest 0.1 cm.

4. The Statistical Design Of The Height And Length Experiment:

Our experiment is "comparative" in nature. Ideally we should have measured one child many times with each possible combination of different observers, instruments and techniques. However, in practice this was not possible, so we decided arbitrarily that each child should have each combination assessed on him only once; if all the combinations were replicated on each child then this would have taken a long time which proved to be beyond the endurance limit of a well behaved child. Statistically we had to establish the number of children needed for our comparison if our analysis was to prove adequate.

Other factors in our study were also considered. Thus it was important to have an environment which was similar to some extent to a survey area. A single child examined at home over a period of 10 days would not have been in any way helpful in determining the likely sources of variability in anthropometry which could develop from a survey done at a crowded roadside in the tropics.

Design of the experiment:

Each child was to be measured with 3 instruments by the Jelliffe and IBP techniques which were both to be used by the two observers. Therefore each child had a series of 12 observations performed in a random manner. Children were chosen randomly from the nursery register but only a third of the children proved sufficiently tolerant to permit all measurements to be made. Theoretically this was a disadvantage since it could be argued that we needed to know the variability of the measurements due to unco-operative children. We found that the average time for each child to be examined in this way was as much as 25 minutes but this time included rest and play periods to allow the child to move and to remain calm.

Sample Size:

Our main problem was in deciding the number of children needed to attain a specified precision in the most economical way. Here the design of the experiment becomes important. We had to obtain valid conclusions and yet consider the practical aspects.

To calculate the sample size the statistical method described by Cohran and Cox (1957) had to be used to detect a given "true difference between means". To show that a true difference between measurements is significant at a given level, we need to know the true standard deviation (σ) of the measurements. We therefore used the standard deviation (SD) found in our Northampton study. This SD is only an approximate estimate because the observers and the methods used previously were different.

The formula for calculating the number of children to be measured is as follows:

$$n \geq 2\left(\frac{\sigma}{\delta}\right)^2 \left\{ t_{\alpha[v]} + t_{2(1-P)[v]} \right\}^2$$

where

n = number of children

σ = true SD

δ = the smallest true difference that we wish to detect

v = degrees of freedom of the sample

α = significance level (e.g. 0.05)

P = desired probability that a difference will be found to be significant

$\left\{ t_{\alpha[v]} + t_{2(1-P)[v]} \right\}$ = values from a 2 tailed "t" table with "v" degrees of freedom and corresponding to probabilities of "α" and 2(1 - P) respectively.

With this formula, the sample size (n) is calculated in an iterative fashion where approximate values for (n) are initially chosen so that a better estimate of (n) can be obtained. An initial estimate of (n) is necessary because without it, we would not know the degrees of freedom for the formula. For the calculation of the sample size, we took

$$a = 3$$
$$\sigma = 0.5$$
$$\delta = 0.5$$
$$\alpha = 0.05$$

therefore the error mean squares will have $v = 3(n-1)$ degrees of freedom. As an initial value for (n) we took 20.

$$20 \geq 2\left(\frac{0.5}{0.5}\right)^2 \left\{ t_{0.05\,[57]} + t_2\,(1-0.80)_{[57]} \right\}$$

where $n = 16.2$. Therefore we tried 16, making $v = 3(16-1)$ $v = 45$ degrees of freedom.

$$16 \geq 2\left(\frac{0.5}{0.5}\right)^2 \left\{ t_{0.05\,[45]} + t_2\,(1-0.80)_{[45]} \right\}$$

$$16 \geq 2\ (1)\left(2.00 + 0.848\right)$$

$$16 \geq 2\ (1)\ (8.13)$$

$$16 \geq 16.1$$

This confirmed that 16 children were needed for the study.

3. The Analysis of the Results.

An analysis of variance was used. Basically we have 4 main effects each of which may either act on their own to produce a component of the total variability in our results or each may interact with another to influence the variability. It is therefore important to analyse which effect has an independent influence in the variability as well as establishing whether a particular interaction for example, of 1 instrument with 1 observer is especially likely to lead to a statistically different result or to an enhanced degree of variation in the values obtained.

Therefore the analysis of variance has to be constructed to take into account 3 instruments, 2 observers, 3 methods and the children themselves ; all these would affect the overall differences and variability in this study. The total variability " V " has the following components.

$$C + I + O + T$$

where

C = child effect

I = instrument effect

O = observer effect

T = technique effect.

However each of these, as already explained interact so that the total variability is given by

$$V = M + C + I + T + CO + CT + CI + OI + OT + TI + R$$

where "M" is the overall mean and "R" is the residual error which can not be accounted for by any of the individual effects listed.

This analysis was then undertaken on the London University Computer which first had to detect whether variability increased with the absolute values for height.

the variability. It is therefore important to analyse which effect has an independent influence in the variability as well as establishing whether a particular interaction for example, of 1 instrument with 1 observer is especially likely to lead to a statistically different result or to an enhanced degree of variation in the values obtained.

Therefore the analysis of variance has to be constructed to take into account 7 instruments, 3 observers, 3 methods and the children themselves : all those would affect the overall differences and variability in this study. The total variability " V " has the following components.

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where C = child effect

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O = observer effect

T = technique effect.

However each of those, as already explained interact so that the total variability is given by

$$V = M + C + I + T + CO + CT + CI + OI + OT + TI + R$$

where "M" is the overall mean and "R" is the residual error which can not be accounted for by any of the individual effects listed.

This analysis was then undertaken on the London University Computer which first had to detect whether variability increased with the absolute values for height.

If this had been so, we would have undertaken a log transformation of the height values. In practice this was not needed. It was still necessary to establish however, that the variability in our measurements had a gaussian distribution, as this is the basic assumption in analysis of variance. Therefore a graphical technique namely, a half normal plot (Figure III.56) was employed to show visually whether the variability in measurements have a gaussian distribution. The plot should approximately show a specified straight line -- drawn in the diagram --. If, the plot deviates greatly from this line it can be concluded that the distribution is not gaussian. However, as can be seen from the graph, the plot is satisfactory. The analysis of variance is used both for height and length experiments.

4. The Results Of the Accuracy Study:

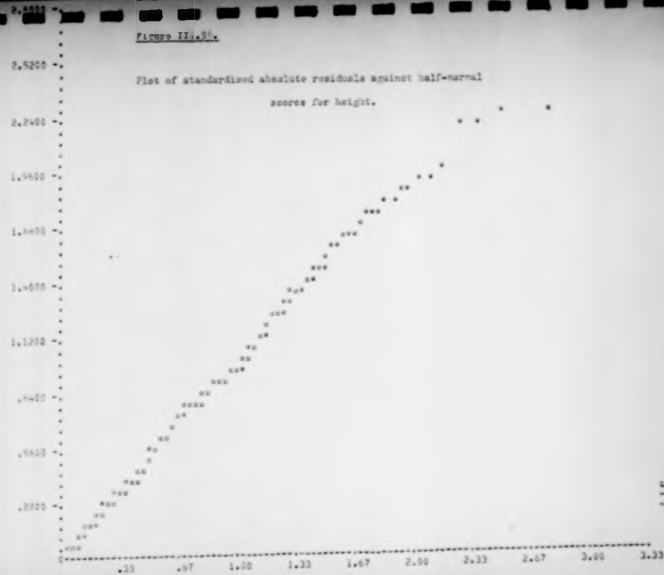
A. Sample Size:

Although the sample size calculated for height and length experiments were approximately 16 children, we could find 14 children for the height experiment and 19 children for length. Both experiments were carried out at two separate London Nurseries for pre-school children.

Since we knew that the standard deviation obtained from the Northampton study was 0.7, it is reasonable to assume that the standard deviation of the height and the length measurements obtained in these experiments would

Figure II.56.

Plot of standardised absolute residuals against half-normal scores for height.



be less since we have a better design which takes other factors into consideration. As a result 0.5 was chosen as a reasonable estimate of the standard deviation.

B. Results of the Height Experiment:

Table III.32. shows the analysis of variance expressed in a general form. The " F " values are listed and "P" values indicate the probability of the particular factor being a significant component of the variation in values obtained in our study. Obviously the difference in children's height was an important component but it can also be seen that other factors contributed to the overall error to a significant extent. A comparison of the Jelliffe and IBP techniques has shown significance but differences between instruments were even more important.

As far as the instruments are concerned four interactions were significenat and two of these, that is the interaction between children and instruments and between the techniques and instruments proved highly significant.

These differences must now be considered in greater detail to see the magnitude of these differences and whether one instrument for example gives very different results.

Table III.71

Analysis of Variance for Height Measurements

	Degrees of freedom	Mean Square	F	Significance
Children	13	981.9280	20096.019	P < 0.01
Observers	1	0.0081	0.167	P > 0.05
Techniques	1	4.3655	89.345	P < 0.01
Instruments	2	8.3121	170.114	P < 0.01
Ch X Obs.	13	0.0232	0.476	P > 0.05
Ch.X Tqs.	13	0.1236	2.529	P < 0.5
Ch.X Ints.	26	0.1127	2.307	P < 0.1
Obs.X Ints.	2	0.3961	8.107	P < 0.05
Obs.X Tqs.	1	0.0508	1.041	P > 0.5
Tqs.X Ints.	2	0.3689	7.551	P < 0.05
Residual	93	0.4488	---	

In this table , Ch. X Obs. signifies the interaction between children and observers, C. X Tqs. is children and techniques, Ch. X Inst. children and instruments, Obs. X Inst. observers and instruments Obs. X Tqs. observers and techniques, Tqs.X Insts. techniques and instruments.

Table III.33.

Mean Height in cm. by Technique

	Jelliffe Technique	IBP Technique	Difference
Mean Height (CM.)	102.6	102.9	0.3

SE = 0.073

Table III.34.

Mean Height in cm. by Instrument

	Holtain Infantometer	Microtoise Height Inst.	Montserrat Toddler Stick I
Mean Height (cm.)	103.1	102.8	102.4

SE = 0.09

Tables III. [illegible] and III. 34. give the mean height for each technique and instrument. The over-all difference between techniques was found to be 0.1 cm. The Holtain Infantometer gave the highest reading and the difference between this instrument and the Montserrat Stick was found to be 0.7 cm. The analysis of variance results for the first order interactions of treatments were found to be significant for the following interactions: the child and technique, child and instruments, observer and instruments and techniques with instruments. Among these the F value of 8.107 and 7.55 on 2 and 93 degrees of freedom were found for observer and instrument and for technique and instrument interactions respectively ($p > 0.01$). Tables III. 35. & III. 36. show the differences between instruments and observers.

As in over-all instrument comparison, the Holtain infantometer gave the highest readings while the Montserrat Toddler Stick gave the lowest. The difference between the two is still 0.7 cm. and this finding is similar to the ones obtained from the over all comparison of instruments. The effect of using different observers seems negligible.

The technique and instrument interactions also showed the fact that the differences are mainly due to the instruments. The IBP technique gave greater height

Table III. 35.

Mean Height in cm. by Observer and Instrument

	Instruments			Differences between	
Observers	Holtain Infantometr.	Microtoise Instrument	Montserrat Toddler S.	Holtain and Montserrat S.	Mocrotoise and Montserrat S.
1	103.1	102.8	102.4	0.7	0.4
2	103.2	102.8	102.3	0.9	0.5

Table III.36.

Mean Height in cm. by Technique and Instrument

	Instruments			Differences between	
Techniques	Holtain Infantomtr.	Microtoise Instrument	Montserrat Toddler s.	Holtain and Montserrat S.	Microtoise and Montserrat S.
Jelliffe	103.0	102.7	102.1	0.9	0.6
IBP	103.3	102.8	[illegible]	0.9	0.2
Difference	0.3	0.1	0.5	0.0	0.4

measurements but the range of difference was 0.5 - 0.1 cm. only.

The differences between observers were not found to be significant but there seemed to be an important interaction between the observers and the instruments. The over-all difference between observers is 0.1 cm.

5. Results of the Length Experiment:

Analysis of variance of length measurements showed that among the main effects only the differences between techniques and instruments were significant where F values were 7.418 and 9.931 on 1 and 28 and 2 and 28 degrees of freedom ($P<0.01$). Table III.27 gives the analysis of variance for length measurements.

The differences in length measurements by technique and by instrument are given in Tables III.31 & III.32.

The Jelliffe technique, as in the height experiment, gave lower values than the IBP technique. The mean increase due to streching is found to be relatively small as expected.

Again differences due to instruments gave significant results and a close analysis reveals the finding that Montserrat Infant Length Stick has lower readings than other instruments.

The interaction of first order effects do not show any significant differences.

Table II.31

Analysis of variance for length measurements

Source	DF	Mean Squares	F	Significance
Children	18	794.4812	2036.780	$P < 0.01$
Observers	1	.1720	.441	$P > 0.1$
Techniques	1	2.8938	7.418	$P < 0.05$
Instruments	2	3.8738	9.931	$P < 0.05$
Child.X Obs.	18	1.2833	3.290	$P < 0.05$
Child.X Teqs.	18	.1467	.376	$P > 0.1$
Child.X Inst.	36	.5598	1.435	$P > 0.1$
Obs. X Inst.	2	.1023	.262	$P > 0.1$
Obs. X Teqs.	1	.0112	.028	$P > 0.1$
Teqs. X Inst.	2	.3714	.952	$P > 0.1$
Residual	128	.3900	----	

In this table, DF signifies the degrees of freedom, Child. X Obs. the interaction between children and observers, Child. Tqs. is children and techniques, Child X Inst. children and instruments, Obs.X Inst. observers and instruments, Obs.X Teqs. techniques and observers, Tqs.X Inst. techniques and instruments.

Table III.38.

Mean Length in cm. by Technique

	Jelliffe Technique	IBP Technique	Difference
Mean Length	88.516	88.743	0.22

SE = 0.036

Table III.39.

Mean Lenth in cm. by Instruments

	Instruments			Differences between	
	Holtain Infantr.	Length Board	Montserrat Infant L.B.	Holtain Mont.S.	Length B Mont. B.
Mean Length	88.780	88.739	88.370	0.40	0.36

SE= 0.071

6. Discussion of the height and length experiments:

1. Observers:

In both height and length experiments the differences between observers were not found to be significant. This is possibly due to the fact that there were only two observers and although one observer was more experienced than the other this factor did not seem to matter because after taking a few measurements the inexperienced observer obviously mastered the technique well. This finding is in agreement with experience in other studies.

The nursery environment may also have helped in limiting the observer variation. Under field conditions, measurements have to be taken very quickly so that reading and recording errrors tend to increase. At the nurseries the working conditions were not as stressful as in field surveys and readings and recordings as well as measurements were made more slowly and carefully.

2. Instruments

The instruments showed significant differences. These differences were expected because of the materials and the designs used in their construction. Although the differences were statistically significant the differences did not exceed 0.5 cm. Microtoise can be used by any field worker under practical conditions because it gave comparable readings to Holtain infantometer which is known to be the most accurate. Montserrat Sticks showed significant differences. Height measurements taken by Montserrat Toddler stick were significantly lower and the difference of 1.0 cm. was observed. We will try to assess the influence of these lower readings due to this instrument in the classification of malnourished children.

3. Techniques:

In the height experiment the difference between the Jelliffe technique and the IBP technique becomes important. The interactions between the instrument and the technique was found to be significant. The IBP technique is slightly more complicated and requires two observers but the choice of technique is in practice usually determined by the type of data required. The longitudinal surveys on growth and development require more accurate and reproducible data than cross sectional surveys of nutritional status.

7. Conclusions From The Analysis Of Variance:

These can be summarised as follows:

1. There were no significant differences between the observers.

2. The Montserrat Toddler Height Stick and Infant Length Stick gave significantly lower values than either the standard Holtain Infantometer or the

Microtoise instrument and this difference amounted to 0.5 - 1.0 cm. for the Toddler Stick and 0.2 - 0.5 cm. for the Infant Length Stick.

3. The Mictotoise, a very simple and inexpensive machine, gave similar readings to the much heavier and more expensive Holtain Infantometer and could be recommended as a useful tool in anthropometry.

4. The differences observed between the IBP technique and the Jelliffe technique are not very significant but the choice of techniques are at ll determined by the type of the study rather than the technique itself.

5. To find out the effects of using the Montserrat Instruments on the Montserrat results a small analysis will be made by applying the percentile method and the numbers of children classified as stunted will be compared.

D. The Time and Motion Study on Skinfold Thickness Measurements

During the Northampton Pilot Study, in addition to the height experiment, an attempt was made to find out the time spent in taking skinfold measurements at 4 sites. The field-workers were timed by a stop-watch while they were measuring different skinfold sites.

Errors in taking skinfold thickness measurements due to both physical measurement errors and observer differences has been a great concern to many workers. Numerous reproducibility and accuracy studies were made. For example, Edwards et. al. (1955) studied observer variability, Imbimbo et. al. (1968) compared three different calipers: Lange, Rizzoli and Harpenden calipers and concluded that these were interchangeable as far as reproducibility is concerned. Burkinshaw et. al., (1973) measured skinfold thickness at biceps, triceps, subscapular and suprailiac sites; the three observers had differing degrees of experience but used the same caliper. Differences between observers were small and of little importance. Womersley and Durnin (1973) investigated the reproducibility of skinfold measurements when different observers and calipers were used as well as the extent of alterations in skinfold thickness in women throughout the duration of menstrual cycle. They found a highly significant observer variability (P>0.01), and significant differences between 2 sides of the body. They found out that while the combination of triceps and subscapular sites gave non-significant results (P<0.05) most of the variability was due to biceps and suprailiac sites.

Womerley and Durnin found 6.2 % variation using the sum of 4 skinfolds, while 9.8 % variation was observed by Brook (1971) when the sum of 4 sites was used for the calculation of body fat. Parizkova (1961) and Parizkova and Roth (1972) showed that the combination of triceps and subscapular skinfolds not only correlated well with body density but also gave the smallest variability. There does not appear to be any uniform agreement on the number of skinfold measurements for field surveys.

Jelliffe (1966) in his Monograph, emphasises on the fact that large numbers of measurements may not be feasible under field conditions and advises to select one or two easily accessible sites they may be expected to give an approximate practical indication of energy reserves. He concludes that triceps skinfold thickness measurement is not only the most practical site but also with the measurement of arm circumference it can be used to calculate the muscle circumference.

It is often said that the collection of subjects is much more time consuming than the measurements themselves, and once they are collected a large number of measurements should be made to justify the costs. However when a field survey is planned, although the choice of measurements are determined to fulfill the purpose of the investigation, factors such as time, money, working conditions, customs and traditions as well as the age group to be surveyed become important.

With this time and motion study we investigated the time spent in taking measurements first at 4 sites separately and then all 4 combined together. We attempted to determine the least time consuming site or combination of sites with the lowes coefficient of variation, the age group which takes the least time to measure and if there were significant differences between two observers measuring the same sites on the same children.

This study was partly an attempt to see whether the time component in field studies should be considered when evaluating the merits of one anthropometric measure in preference to another.

1. Methods of timing the skinfold thickness measurements:

Two field-workers using identical Harpenden calipers were timed with a sop-watch while they were measuring skinfold thicknesses at four different sites, namely triceps, biceps, subscapular and suprailiac separately. Altogether observations on 37 children were collected.

a. Triceps skinfold measurement:

Timing of triceps site was in two parts: from the time the field-worker touched the child's arm to feel the acromial process of the scapula (to measure the distance between this process and the olecranon process of the ulna) until she completed marking the child's arm at the mid point, from the time she picked up a skinfold parallel to the long axis of the arm until the reading was recorded.

b. Biceps skinfold measurement:

Timing started when the field-worker extended the mid-point mark to the anterior aspect of the arm and stopped when she finally recorded the measurement.

c. Subscapular and Suprailiac skinfold measurements:

For the subscapular site, the stop watch was started when the field- worker touched the child's back to feel the inferior angle of the left scapula. For the suprailiac site the same procedure was repeated at the top of the suprailiac crest. Field-workers took 2 repeated measurements at each site and each individual measurement was timed. Only 2 field-workers who worked at the clinics throughout the study could be timed.

2. Results of Time and Motion Study:

The coefficient of variation of skinfold measurements based on observations on 37 children by 2 field- workers are given together in Table III.40.

Although biceps site seems to be the less time consuming, its coefficient of variation is the highest among all. The difference in time spent in measuring triceps, subscapular and suprailiac sites are quite similar but subscapular site gives the lowest coefficient of variation. The combination of triceps and subscapular sites has the lowest coefficient of variation (CV) and takes about 1 minute and it appears to be the most appropriate. This combination not only have the lowest CV but also have been shown to be well correlated with body density (Parizkova, 1961; Parizkova and Roth, 1972). The time spent on these two sites together with mid arm point is less than the time spent on 4 sites.

The differnce between observers in the time taken for each measurement was then analysed as shown in Table III.41 . These results showed no significant differences, both observers seem to have spent similar amount of time on these measurements.

The effects of different ages:

Although the total sample size was not very large children were grouped in 3 age groups. It was thought that smaller the children it becomes more difficult and takes longer to measure the skinfold thicknesses. For example, 4 year olds are possibly more co-operative than 2 year olds. Table III.42. shows that there are no

Table III.44.

THE MEAN TIME SPENT IN MEASURING SKINFOLD THICKNESSES

Number of Children	Arm Mid Point	Time in seconds					
		Triceps	Biceps	Subscapular	Suprailiac	Sum of 4	Triceps + Subscapular
37	29.90	24.60	17.89	25.36	27.81	127.4	50.16

Table III. 40.

COEFFICIENT OF VARIATION OF SKINFOLD MEASUREMENTS BASED ON

MEASUREMENTS ON 37 CHILDREN BY 2 FIELD WORKERS

Number of Children	Arm Mid Point	Time in seconds					
		Triceps	Biceps	Subscapular	Suprailiac	Sum of 4	Triceps + Subscapular
37		[illegible]	[illegible]	9.7	19.6	10.7	[illegible]

Table III.41.

THE DIFFERENCE BETWEEN THE 2 OBSERVERS IN TIME SPENT WHILE TAKING SKINFOLD THICKNESS MEASUREMENTS

Field Workers	Time in Seconds						
	Number of Children	Mid Arm Point	Triceps	Biceps	Subscapular	Suprailiac	Sum of 4 sites
1	14	30.80	30.36	15.35	24.92	27.57	129.00
2	15	28.30	26.32	18.40	25.86	26.00	125.20

Table III. 42.

Time difference between age groups

Age Group in Years	Time in Seconds					
	Number of Children	Triceps + Mid arm point	Biceps	Subscapular	Suprailiac	Sum of 4 sites
2	8	69.25	17.12	22.62	41.26	150.25
3	15	47.86	17.20	26.13	26.40	117.60
4	13	55.61	18.46	22.24	24.61	120.92

significant differences between the 3 age groups observed. However there was certainly an evidence that the supra-iliac and the triceps were particularly more time consuming in the youngest group.

Lastly the time spent on biceps, suprailiac and subscapular sites were compared with the triceps + mid arm point time for it is necessary to measure the mid arm point before taking triceps skinfold measurement. The total triceps takes the longest time with a mean of 55.50 seconds and not surprisingly there was a significant difference between the comparisons. The "t" values and the significance levels were given in Table III.43.

Table III.43.

The comparison of total triceps time with the other 3 skinfold measurement times:

Sites	D.F.	t	P
Biceps	72	8.9	< 0.001
Subscapular	72	6.9	< 0.001
Suprailiac	72	6.4	< 0.001

SECTION IV

[illegible]

IV. 1. THE USE OF WEIGHT FOR HEIGHT AS A NUTRITIONAL INDEX

When the analysis of this data was begun the use of weight for height was just beginning to emerge as a useful addition to the analysis of anthropometric information obtained for the assessment of the nutritional state of children. Seoane and Latham (1971) drew attention to the importance of analysing data in terms of weight for height because they felt that this would prove to be a useful index of wasting. This suggestion was not new for Franzen (1929) also emphasized its importance and even at that stage the importance of assessing weight in terms of height was self evident to adult physicians dealing with patients with either obesity or wasting diseases.

During the survey in Montserrat it became clear that many of the children who were classified under the Jelliffe scheme as "malnourished" appeared to be clinically well, active and of normal body proportions. It then emerged that we were dealing with many children who were short for their age and that if this were taken into account then a much smaller proportion of children would be classified as malnourished if we define malnutrition as a condition primarily associated with wasting. However this requires a choice of an appropriate "cut-off"point on the weight for height scale below which children could be classified as malnourished. The use of just a weight for age system of analysis appeared to be too crude since variability in weight included in part the variability associated with differences in height.

This important nutritional principle in fact is apparent from the analysis of the standard data itself. Table III. 25. compares the coefficient of distribution for both weight for age and weight for height at each age interval. This is a striking illustration of how, even in a healthy population,this difference in distribution is considerable.

The problem then was to devise a system by which the differences in the analysis of weight could be demonstrated. Since then Waterlow has presented a classification grading the severity of malnutrition by using weight for height and height for age in a composite manner (Waterlow, 1972). We have accordingly analysed our data in this way. Originally he used a

4X4 table illustrated in Table IV. 1, which contained our Montserrat data.

Table IV. 1.

Example of 4X4 Classification according to Degree of Malnutrition and Retardation. Percentages are Proportions of Children Examined.*

			Retardation			
		Grade	0	1	2	3
		% Expected height for age	95	95 -87.5	87.5-80	80
		% Expected weight for height	%	%	%	%
Malnutrition	0	90	52	31.5	3	1
	1	90-80	2	7.0	0.5	0
	2	80-70	1	2.0	0	0
	3	70	0	0	0	0

* Waterlow, C.J., British Medical Journal. 1972,3. 566-569

In this table the choice of height intervals was arbitrary. The choice of all the grading intervals on the weight for height scale was also arbitrary and in practice was chosen so that one of the cut-off points in grading was 80 % i.e. corresponding to the

80 % cut-off point as used by Jelliffe for both weight for age and weight for height. The 80 % weight for age had some statistical validity as a cut-off point since this corresponded to the 3rd percentile for weight for age, but no similar analysis had been undertaken for the weight for height scales. Subsequently Waterlow (1973) changed his system of classification for height for age because he believed that the standard deviation for height was 5 % and therefore he used 5 % grades for classifying height for age.

The Montserrat data was therefore analysed in these terms and this classification is presented in Tables IV. 2., IV. 3., IV. 4., IV. 5.

Although in theory all children could be classified in one table thus eliminating the problem of presenting data for children of different ages yet we wished to see whether there were important differences in the results from children at different ages.

The most striking effect of this analysis is to reduce substantially the number of children who are malnourished, i.e. "wasted". The data from children aged 6 - 24 months demonstrates that only half the children considered "abnormal" on the basis of their weight or height are wasted, the other half being short but of normal body proportions.

Table IV. 2.

Montserrat Children Classified by

Waterlow's 4 X 4 System.

(Sexes combined, 0 - 5 months)

Proportions of children

			Retardation			
		Grade	0	1	2	3
		% Expected height for age	95	94-90	89-85	85
		% Expected weight for height	%	%	%	%
Malnutrition	0	90	71.7	20.0	1.1	1.1
	1	90-80	4.7	0	0	0
	2	80-70	1.1	0	0	0
	3	70	0	0	0	0

Table IV. 3

6 - 11 months

			Retardation			
		Grade	0	1	2	3
		% Expected height for age	95	94-90	89-85	85
		% Expected weight for height	%	%	%	%
Malnutrition	0	90	71.7	13.1	0	1.1
	1	90-80	9.0	1.1	0	0
	2	80-70	2.0	1.1	0	0
	3	70	1.1	0	0	0

Table IV. 4.

Waterlow Classification cont.

(12 - 23 Months)

proportions of children

			Retardation			
	Grade		0	1	2	3
	% Expected height for age		95	94-90	89-85	85
		% Expected weight for height	%	%	%	%
Malnutrition	0	90	56.0	22.7	4.3	2.4
	1	90-80	4.8	6.2	0.9	0
	2	80-70	0.9	0.9	0	0
	3	70	0.4	0	0	0

Table IV. 5.

24-36 Months

			Retardation			
	Grade		0	1	2	3
	% Expected height for age		95	94-90	89-85	85
		% Expected weight for height	%	%	%	%
Malnutrition	0	90	63.0	19.4	3.8	0.9
	1	90-80	5.7	2.8	0.9	0
	2	80-70	1.4	1.4	0	0
	3	70	0	0.4	0	0

It is clear, however, that a great deal must depend on the choice of cut-off points particularly for the weight for height values and this to date have not been assessed by any worker.

Waterlow has chosen the cut-off points he has used for his 4 X 4 classification from the weight for height data obtained in Malawi (Burgess et al., 1973). In this population a standard deviation for weight for height values has been calculated for children between 50 and 119 cm. tall as 10 % of the mean values. However these children can not be considered as appropriate as a standard population since about 35 % of 12-17 month olds were considered malnourished by the Jelliffe classification. Clearly there is therefore a need to re-evaluate this problem since it would otherwise be just as approximate to use Montserrat data for this purpose.

A. The Choice Of Cut-off Points For Weight For Height:

In Section III.4. we discussed the different types of standard data available at some length and concluded that the Dutch data was the most useful. Van Wieringen (1972) presented only the 10th, 50th and 90th percentiles without any information on the standard deviations because it is recognised by all that weight for age and weight for height within most populations do not have a Gaussian distribution and this was illustrated for weight in our Montserrat analysis (Figure III.[illegible]).

In the absence of information on the 3rd percentile and with the widespread use of arbitrary cut-off points we felt that it would be justified to try to obtain 3rd percentile values from the best data available i.e. the Dutch standards. Since weight for height values are often considered to be skewed (although in practice this problem does not seem to have been analysed for children's data) a system of analysis based on the assumption of a Gaussian distribution is considered inappropriate. However, many workers are concerned with defining the upper limits of weight for height i.e. in the region where the skew becomes important. We, however, require the use of the lower half of the distribution where the scatter of values is much closer to the "normal" distribution.

We therefore calculated the 3rd percentile as corresponding to 1.88 standard deviations in the distribution, the 10th percentile Dutch value being taken as corresponding to [illegible] standard deviations from the mean value i.e. as in the Gaussian distribution ([illegible], Tables for Statisticians and Biometricians [illegible] Ed., Part I. The University Press, London, 1948).

Table IV. A.

The Calculated 3rd Percentiles derived from the Dutch Standards for Children from Birth to 4 Years of Age.

Height in 2 cm. int.	Age in Days 0 - 89	90 - 179	180 - 269	270 - 359
	kg. %	kg. %	kg. %	kg. %
50 - 51	2.89 ([illegible])			
52 - 53	3.16 (85.0)			
54 - 55	3.52 (85.0)			
56 - 57	3.86 (84.0)			
58 - 59	4.39 ([illegible])	3.97 (71.8)		
60 - 61	4.66 (85.0)	5.08 (87.0)		
62 - 63	4.99 (83.2)	5.30 (84.9)		
64 - 65		5.70 (85.3)		
66 - 67		6.14 (84.9)	6.77 ([illegible])	
68 - 69		6.48 (84.9)	6.95 (85.5)	
70 - 71		7.03 (83.7)	[illegible]	7.43 (84.0)
72 - 73			7.62 (84.0)	8.15 ([illegible])
74 - 75			8.31 ([illegible])	8.54 (87.1)
76 - 77				8.91 (86.3)
78 - 79				9.22 (85.0)
80 - 81				
82 - 83				

Table IV, A. Continued.

Height in 2 cm. int.	Age in Days							
	350-540		541-721		721-901.		902-1081	
	kg.	%	kg.	%	kg.	%	kg.	%
74- 75	7.94	(81.9)						
76- 77	8.06	(84.6)						
78- 79	9.18	(85.0)						
80- 81	9.44	(82.1)	9.74	(84.7)				
82- 83	10.04	(83.0)	9.89	(83.8)				
84- 85	10.50	(82.7)	10.49	(84.6)	10.53	(87.8)		
86- 87	10.74	(83.9)	10.60	(83.8)	11.04	[illegible]		
88- 89			11.15	(82.6)	11.54	(86.8)	11.93	(88.4)
90- 91			11.99	(86.3)	11.89	[illegible]	11.70	(84.2)
92- 93			12.44	(85.6)	12.20	(84.7)	12.44	(87.6)
94- 95					12.60	[illegible]	11.28	(76.2)
96- 97					13.10	(85.6)	13.34	[illegible]
98- 99							14.33	(90.7)
100-101							14.87	(95.3)
102-103							14.95	[illegible]
104-105								
106-107								
108-109								

Figures in parenthesis are the calculated 3rd percentile expressed as a percentage of the 50th percentile.

The 3rd percentile values for weight at each height interval were calculated for all the age groups given by Van Wieringen in his Tables 8.4 and 8.5. The data for boys is presented in Table together with the calculated % of the median weight.

From these tables it can be seen that a choice of 85 % of the median would correspond most closely to the probable 3rd percentile values over the whole age range. The effects of using these cut-off points will be considered below.

B. The Choice Of Cut-off Points For Height:

If the cut-off point for height is going to be chosen on the same basis as the cut-off points for weight for age or weight for height then we need to establish the standard deviation for height so that 2 standard deviations below the mean can be taken as the cut-off level.

An analysis of the Harvard standards for the whole pre-school age children shows that the 3rd percentile corresponds to approximately 95 % of the median which implies that the standard deviation is approximately 2.5 %, not 5 % as suggested by Waterlow (1973). Similarly an analysis of the Dutch data suggests a standard deviation of 3.2–3.4 % for their figures. On this basis it seems logical to take 95 %

as the cut-off point (as suggested by Waterlow who preferred to use what he considered to be 1 standard deviation from the mean rather than 2 standard deviations).

C. The Choice Of Limits For Different Degrees Of Deficit In Weight, Height and Weight For Height:

Hitherto the choice of limits appearsto have been arbitrary. Jelliffe's classification for weight for age has the advantage that each interval is 10 % and this is equivalent to 1 standard deviation. It would appear logical to use the same principle for all measurements, i.e.choosing the 1st degree of deficit as including all values between 2 and 3 standard deviations below the standard mean, the second degree for values between 2 and 4 times the standard deviations below the mean and the 3rd degree to include all values which lie more than 4 standard deviations below the mean.

Table IV.6. categorizes the deficits for heights of the children below 3 years in terms of the standard deviation of 2.5 %. It is clear that an appreciable proportion of children fall below the 4 standard deviations level, i.e. corresponding to 90 %. This level would seem to be statistically appropriate although Waterlow lumped 2 standard deviations categories together

Table IV. 6.

The Percentage Of 0-3 Year Old Children Falling Into Each Height For Age Bracket

S.D.	% Standard height	Age in months				
		0 - 5	6-11	12-23	24-35	Total
1	97.5	46.9	45.7	31.6	41.8	39.3
2	95.0-97.5	21.6	28.7	24.0	19.2	22.9
3	92.5-95.0	18.0	18.0	17.4	16.3	17.3
4	90.0-92.4	10.8	5.3	15.5	12.9	12.3
5	87.5-89.9	0	1.1	6.1	6.2	4.4
6	85.0-87.4	1.2	0	2.3	2.2	1.8
6	85.0	1.2	1.1	2.8	1.1	1.8

so that a 3rd degree "retardation" (in his terms) was only present if the child fell below 85 % of the standard height, i.e. six times the standard deviation interval from the mean.

It should be pointed out again at this stage that these children's height deficit does not appear to be solely genetically determined since very great changes in height distribution occur in the second year of life. However, it is difficult to be sure that genetic factors are not involved since even in the 0 - 6 month old group there are 11.2 % of children below 95 % of the standard. On this basis alone, however, we are unable to decide the relative contributions of genetic and environmental factors to this initial height deficit.

Table IV. 7. classifies this same group of children on this new system. The severity of the height deficit is much more obvious whereas the deficit in weight for height is relatively small. Deficits in weight for age occupy an intermediate position as expected.

Before this analysis is considered further, the Montserrat data will be presented as analysed by the 3 methods suggested by Jelliffe in 1966, Waterlow in 1973 and by McLaren and Read in 1972 and 1975. McLaren and Read's system must however be considered first.

Table IV.7.

Classification of weight for age and weight for height and height for age values with the deficit related to the S.D. of a normal population

(proportions of children below 36 months) in each category

Number of Intervals *	Degree of Deficit	Weight For Age	Weight for Height	Height for Age
0 - 1	0	65.1	79.5	39.3
1 - 2		22.6	13.7	22.9
2 - 3	1	10.0	5.2	17.3
3 - 4	2	1.7	1.2	12.3
4 - 5		0.5	0.2	4.4
5 - 6	3	0	0	1.8
6		0	0	1.8

* Number of intervals (as S.D.) below mean for normal population.

D. McLaren and Read Classification:

McLaren and Read (1972) proposed a classification of nutritional status based on weight height and age. The relationship of weight and height is expressed by dividing the weight (in grams) by the height (in centimeters) and then expressing the result as a percentage of the standard quotient derived from the Harvard data for a child of the same age.

Table IV.8

McLaren and Read Classification(1)

Classification	Observed weight as % of ideal weight/length/age
Overweight	110
Normal range	90- 110
Mild P.E.M.	85- 90
Moderate P.E.M.	75- 85
Severe P.E.M.	75

(1) McLaren, S.D., and Read, C.W.W., The Lancet,ii,1972, pp. 146-148.

The method by which the weight/height/age quotient is derived is completely empirical and their choice of cut-off points is also arbitrary. A value of 110 % or more was taken as the cut-off point for classifying children as overweight because this value fitted well with that reported by Iomon (1967). As the upper limit for normal was only 10 % more than the standard, 90 % of the standard was then taken as the lower range of normal. Similarly 75 % of the derived standard was taken as the borderline for severe P.E.M. because this practically coincided with the 60 % of the standard weight for age value which is widely accepted as the cut-off point for severe P.E.M. The 60 % of course negates the whole purpose of the analysis since McLaren and Read presumably hoped to derive formulae which would provide more information than that gained from a simple weight for age classification. If they chose the limits for 3rd degree malnutrition as those corresponding to the ones for severe and clinically obvious P.E.M. then presumably the other grades were designed for greater precision or sensitivity in the assessment of malnutrition. The subsequent analysis will show that this is not necessarily true, but Table IV.9. presents the data from the 0 - 3 year old Montserrat children in the format prepared by McLaren and Read.

An important feature of McLaren and Read's classification is that the quotient obtained from the Weight/Height calculation normally increases with age and the rate of increase is most marked in the first few months of life. The effects of this mathematical manipulation will become obvious later.

Table IV.9.

Classification of the 0-3 year old Montserrat Pre-school population by the McLaren and Read Method.

Classification	No.	%
Obese	24	4.1
Overweight	59	10.2
Normal	341	59.3
Mild P.E.M.	92	16.0
Moderate P.E.M.	40	7.0
Severe P.E.M.	19	3.3
Total	575	100.0

Table IV.10. summarises the cut-off points used the classification by Jelliffe (1966), Waterlow (1972), and McLaren and Read (1972).

Table IV.11. compares the percentages of children classified as having different degrees of P.E.M. taking Waterlow's initial emphasis on weight for height as equivalent to malnutrition. Our own classification with the new cut-off point (illustrated in Table IV.11) is also included. Here the surprising finding is the close agreement between the Jelliffe and Waterlow classifications despite their being based on different concepts. Waterlow's cut-off points for weight for height were too broad in the original 4X4 table (see Table IV.1) which was designed to emphasize retardation in height and in fact we can now see that the true extent of the wasting was even less than that specified by Waterlow who in practice included some deficit in weight related only to a deficit in height.

McLaren's classification is strikingly different and much more closely allied to the deficit in height column despite the apparent emphasis on weight in his quotient.

To illustrate the source of confusion between the McLaren and Read and Waterlow systems we have taken

Table IV.10

A Comparison Of The Classification Methods of Jelliffe, Waterlow and McLaren and Read

Index	Jelliffe				Waterlow				McLaren and Read			
	Normal	Mild Maln.	Moderate Maln.	Severe Maln.	Normal	Mild Maln.	Moderate Maln.	Severe Maln.	Normal	Mild Maln.	Moderate Maln.	Severe Maln.
Weight/Age	81	80-70	69-60	60								
Height/Age	91	90-81	80-71	70	95	95-90	89-85	85				
Weight For Height	81	80-79	70-69	60	90	89-81	80-71	70				
Weight/Height Age									110-[illegible]	[illegible]	[illegible]	75

Table IV. 11

A comparison of 4 different approaches to the classification of P.E.M.

Data analysed for the 0 - 36 months old children.

Classification	Jelliffe	Waterlow	McLaren	This Thesis	
Anthropometric Index	weight for age,% of standard	weight for ht.,% of standard	weight/height/age quotient	weight for ht.,% of standard	height for age,% of standard
Normal	87.8	87.3	73.3	93.2	62.2
1st. degree	10.0	9.8	16.1	5.2	17.3
2nd. degree	1.7	2.3	7.0	1.2	12.3
3rd. degree	0.5	0.5	3.4	0.2	8.0

3 hypothetical children at the age of 3, 6 and 12 months each of whom was 91 % of the expected height for age and 91 % of the expected weight for this height.

Table IV. 12. shows that on the original Waterlow system these children are graded as normal in terms of malnutrition (although slightly "retarded") whereas McLaren and Read classify them as "moderately malnourished".

McLaren and Read's system therefore emphasizes height deficit in particular but it has the virtue of giving greater prominence to growth failure in the first few months of life than to growth failure at the age of 2 or later when the increment in weight/height is very much smaller. This classification automatically includes a series of judgements about what is important in nutritional terms and being a composite measurement it is difficult to use in meaningful terms to analyse the pattern of growth in early life, since a change in quotient may either reflect changes in weight or height and a quotient of 90 % will mean very different deficits in weight in a 3 months or 3 years old child. Thus an arrest in growth for 1 month when the child is 3 months old will have a very profound effect on the quotient.

Table IV. 12.

An illustration of the effects of the Waterlow and McLaren Classifications for children aged 3, 6 and 12 months of age who are 91 % of the standard height and 91 % expected weight for height.

	Age in months		
	3	6	12
Height in cm.	54.6	59.9	67.2
Weight in kg.	4.2	5.2	7.4
McLaren Quotient %	80.7	77.0	83.0
McLaren diagnosis	Mod. P.E.M	Mod. P.E.M	Mod. P.E.M.
Waterlow grading of P.E.M.	O	O	O

It seems reasonable to conclude therefore that much of the present controversy about classifying P.E.M. relates to differences in approach and to the use of derived anthropometric indices which imply very different nutritional concepts.

Although somewhat cumbersome, a separate analysis of weight for height and height for age deficit is appropriate in that it provides more information and any judgement about the nutritional significance of either deficit can then be clearly stated and analysed appropriately.

Since however, many anthropometric surveys make use not only of weight and height but in particular emphasise the importance of limb measurements for assessing nutritional state, we have extended our analysis to see what the relationships are between weight for height deficits and arm measurements with the prime purpose of defining the suitable cut-off points for triceps skinfold thickness, muscle and arm circumferences.

First, we undertook a correlation analysis to establish the relationship between the various indices.

IV.2. The relationship of arm measurements with weight and height:

Correlation analysis has been widely used in analyses of the importance of different indices of nutritional status (Nammacher, Bradfield and Arroyave, 1972; Williamson-Rueda, 1962).

This approach is often limited since the starting point has usually depended on the choice of an agreed definition of malnutrition with which to compare any other index (Crispin et. al., 1968; Rao and Singh, 1970; Dugdale et. al., 1970). For example, Rao and Singh (1970) in their work in India, classified 3,100 Indian pre-school children into 3 groups of normals, children with signs of vitamin deficiencies and children with P.E.M. They assessed the relative importance of different anthropometric measurements in the assessment of P.E.M. Protein energy malnutrition was defined both clinically and in terms of weight for age, the cut-off point being taken as 80 % of the Harvard Standard weight for age. Rao and Singh's work could have shown for example that arm circumference was more reduced in the children with P.E.M. than weight. On this basis one might consider the use of arm circumference as a preferable index to weight. Unfortunately they did not analyse their data in this way but were content to show relationships between the anthropometric measurements in the different groups of children. They did however attempt to discriminate change in adiposity from changes in lean body mass by looking at the weight/height^2 index in their 3 groups. They observed a close relationship between the severity of P.E.M. on the one hand and weight, weight/height, and calf circumference measurement on the other. Weight/height^2 was significantly lower in children who were vitamin deficient. This index was suggested as useful in detecting early cases of P.E.M. in field studies.

There are of course numerous studies where skinfold measurements are related to weight as an independent measure of body fat but these differ from Dugdale's study (1970) in that there is a base-line with which to compare the anthropometric measures. Dugdale's analysis in common with our own, depends on making some assumptions about how one defines nutritional state.

A. Application of Correlation Analysis to Anthropometric Data:

The relationship between anthropometric parameters as indices of nutritional state was assessed by correlation analysis. Matrices of product moment correlations between the different anthropometric parameters were calculated. Analyses were also performed with the data from both sexes combined.

When this method of anaysis was applied to the data from the whole pre-school group, problems arose because this method assumes that parameters are distributed in a gaussian manner and that the variables are not interdependent even in their relationship to age.

To overcome these problems we could have employed a partial correlation analysis as used by Dugdale. This would then have excluded the effects of age. Instead, we tried to eliminate the age dependency by grouping the data in separate age groups and then by expressing all our parameters as a percentage of the standard. Thus the data on weights and heights of 6 month olds was comparable with those of 4 year olds. It is of course possible that by introducing the use of a "standard" (Harvard standards as used previously) we might be creating a bias to some extent towards one measurement rather than another. This does not, however, seem to be a major problem as can be shown merely by comparing height and weight correlation coefficients first expressed on an absolute basis, i.e. heights in cm. and weights in kg. units, and secondly as the percentage of the standards. This comparison is given in Table IV, 13.

Table IV.13

Correlation coefficients between height and weight: the comparison of coefficients derived from the absolute and relative values, i.e. cm. against kg. and %ht. against % wt.

Age Groups	Absolute value	Relative value	Significance of difference (%)
0 - 6	0.798	0.659	NS
7 - 12	0.695	0.619	NS
13 - 24	0.676	0.680	NS
25 - 36	0.788	0.767	NS
37 - 48	0.752	0.746	NS
49 - 60	0.720	0.724	NS

For this comparison, the correlation coefficients between height and weight were chosen because the relationship of these two parameters were considered relatively more linear than the other anthropometric measurements. According to the above table, the coefficients are very similar and the differences are very small.

The relative values are lower than the absolute values in 4 of the 6 age groups. However in the first year group the absolute value seems better than the relative one.

These differences do not mean that one method is better than another. A " Z " test was used to show that these differences were not statistically significant and different from each other. They seem to be in good agreement with [illegible]'s results and partial correlation analysis does not seem to be necessary. On the other hand by calculating the coefficients for individual age groups we have already minimized the age effects.

The Montserrat pre-school group was divided into 7 age groups and the correlation coefficients were calculated for both sexes both as combined data and separately. A brief summary of results is given below.

B. <u>Correlations with height:</u>

Correlations of height with weight, arm circumference and muscle circumference are significantly different from zero for all age and sex groups. The relationships were found to be much higher for weight. Table IV.14. gives the correlation coefficients (henceforth called " r " values) for all the age groups.

Table IV.14.

Correlations of height % with weight, arm and muscle circumference values

Age Groups in months	WEIGHT %		ARM C. %		MUSCLE C.%	
	Boys	Girls	Boys	Girls	Boys	Girls
0 - 6	0.82	0.75	0.62	0.49	0.62	0.55
7 - 12	0.66	0.71	0.48	0.52	0.39	0.31
13 - 18	0.74	0.66	0.36	0.22	0.40	0.20
19 - 24	0.83	0.76	0.49	0.24	0.47	0.33
24 - 36	0.69	0.75	0.40	0.51	0.40	0.53
36 - 48	0.70	0.76	0.30	0.30	0.27	0.25
48 - 60	0.69	0.70	0.44	0.39	0.44	0.43

Despite these high values shown above, the r values between height and skinfold thickness measurements in all age-sex groups were not significantly different from zero so that we can say that height is independent of skinfold thickness at all age groups in both girls and boys ($P > 0.05$). Table IV.15 gives the r values between height and weight for height percent and weight/height^2.

Table IV.15

Correlations of height % with weight for height% and weight/height^2 for both sexes separately.

Age classes in months	WEIGHT FOR HEIGHT %		WEIGHT/HEIGHT^2	
	Boys	Girls	Boys	Girls
0 - 6	0.08	-0.09	0.21	0.19
7 - 12	-0.15	-0.15	-0.06	0.00
13 - 18	0.31	-0.40	0.20	-0.44
19 - 24	0.04	-0.21	-0.10	-0.03
25 - 36	-0.27	0.28	-0.45	0.00
37 - 48	0.24	0.12	0.12	-0.08
49 - 60				

Here again there were no significant relationships and this is an important confirmation of the independence between height and weight for height and weight/height^2.

C. Correlations with weight:

For all age and sex groups weight correlated well with all anthropometric parameters except triceps skinfold thickness where the r values were low. Coefficients between weight and height, arm circumference, muscle circumference, weight for height and weight/height^2 were all found to be significantly different from zero at the 1 % probability level. Although triceps skinfold thickness is reported to be a good indicator of weight, this is not true for Montserrat children.

D. Correlation with triceps skinfold measurements:

It has been previously shown that triceps skinfold thickness measurements of Montserrat children in all age groups were below the standards. Although the r values between weight and tricepes skinfold thickness were significantly different from zero the values obtained were much lower than expected. Table IV.16 gives the r values of triceps skinfold thickness with weight as well as with other indices of adiposity such as weight for height and weight/height^2.

These values are surprisingly low but the correlations with weight for height and with weight/height^2 are higher than for weight for age alone.

Table IV.16

Correlations of triceps skinfold thickness % with weight % weight for height% and weight/height^2 for both sexes given separately.

Age groups in months	WEIGHT %		WEIGHT FOR HEIGHT%		WEIGHT/HEIG	
	Boys	Girls	Boys	Girls	Boys	Girls
0 - 6	0.14	0.45	0.17	0.41	0.15	0.53
7 - 12	0.34	0.21	0.55	0.27	0.54	0.30
13 - 18	0.42	0.14	0.49	0.29	0.49	0.21
19 - 24	0.37	0.10	0.46	0.32	0.36	0.41
25 - 36	0.23	0.42	0.18	0.55	0.13	0.55
37 - 48	0.47	0.06	0.58	0.26	0.58	0.29
49 - 60	0.32	0.33			0.20	0.54

These correlations do of course only give some indication of the general relationship between one index and another. It seems quite clear that there is very little relationship between triceps skinfold and other measures of body composition and this seemed surprising.

We do already know however, from this analysis that the children in Montserrat seemed underweight and underheight with in general small skinfold measurements.

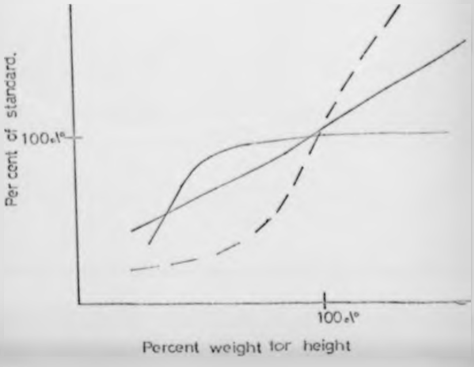
E. The Nutritional Significance of Small Skinfold Measurements:

It seemed possible therefore that we were dealing with children who were thin and that the relationship between skinfold measurement and weight might only apply to comparatively well nourished children.

This approach might have important implications because it seemed possible that the definition of a suitable cut-off point for triceps could be undertaken not on statistical grounds but on nutritional grounds as well. This is illustrated schematically in Figure IV. 1. Here we can see fat being preferentially used as a child's weight and weight for height falls below the norms until the skinfold values reach a low value below which as the child loses more weight the skinfold measurement changes only slowly. During this stage of weight loss the child has to call on resources other than adipose tissue and the muscle circumference would then fall as muscle mass decreased. A point at which a fall in weight for height is accompanied by an appreciable reduction in muscle mass could then be taken as an appropriate level or "cut-off point" for triceps and for arm and muscle circumferences below which a child could be classified

Figure IV. 1.

POSSIBLE RELATIONSHIPS BETWEEN BODY FAT AND LEAN BODY MASS DURING WASTING AS INDICATED BY CHANGES IN LIMB MEASUREMENTS



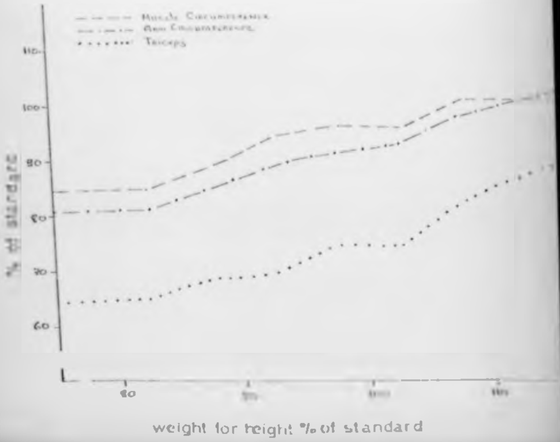
as at risk. We looked at this problem by selecting a group of children who were likely to be "malnourished", that is 1 - 2 year old from the Montserrat pre school age group. We also compared the relationship with a similar analysis conducted on the data collected from normal children aged 2,3 and 4 years in Northampton.

This analysis was undertaken first by grouping the children on the basis of their weight for height expressed as the percentage of the standard and grouped in 5 and 10 % intervals. Then the mean triceps, arm and muscle circumference values were calculated for each group the values being expressed in each child's case as a percentage of the standard for that age and sex. This allowed several age groups and the sexes to be combined. The results are shown in Figure IV.2.

The most striking feature of Figure IV. 2. is that the 1 - 2 year old Montserrat children have lower arm circumferences than expected on the basis of their weight for height. This seems to be mostly accounted for by the previously noted small triceps measurements. Thus even in obese children over 110 % weight for height the triceps values were still below 90 % of the standard. There was, however, a marked reduction in triceps measurements in these children with lower weights for height.

Figure IV 2

THE RELATIONSHIP BETWEEN ARM MEASUREMENTS AND WEIGHT FOR HEIGHT IN MONTSERRAT PRE-SCHOOL CHILDREN 1-2 YEAR OLDS.



However, below 90 % of the standard weight for height there seemed little further reduction in skinfolds and at this stage there seemed to be an appreciable fall in muscle circumference. This therefore in general fitted well with the hypothesis.

Figure IV. 3. shows the same analysis of the Northampton data. Here in contrast to Montserrat, arm and muscle circumferences and skinfold measurements were above the standards when the children's weights for height were more than 100 %. However, the relationship between these arm measurements and the weight for height was in general consistent with the hypothesis outlined in Figure IV. 1., with triceps values falling very rapidly between 100 % and 85 % weight for height.

In order to be sure that the difference between the communities was not solely an age difference, a similar analysis was undertaken on the data from 2 -3 year old children in Montserrat and in general the same relationship was found as in 1 - 2 year olds (Figure IV.4). Figure IV. 5. compares the Northampton and Montserrat arm circumference and skinfold values, the data being taken from children of comparable ages. Both the Montserrat and Northampton children's measurements for arm circumference and skinfold seem responsive to reductions in weight for height but a much more pronounced change seems to have occurred in the Northampton children. Thus the limb mass seems to

Figure IV 3.

THE RELATIONSHIP BETWEEN ARM MEASUREMENTS AND WEIGHT FOR HEIGHT IN NORTHAMPTON PRE-SCHOOL AGE CHILDREN 2-3-4 YEAR OLDS.

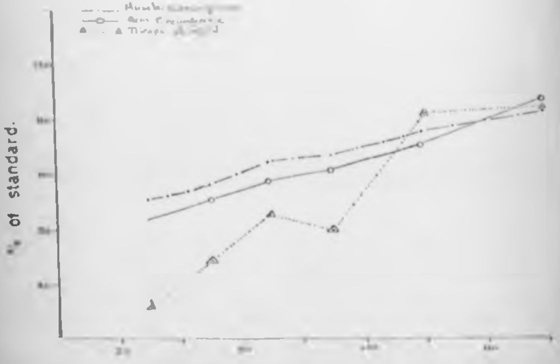


Figure IV.4

THE RELATIONSHIP BETWEEN ARM MEASUREMENTS AND WEIGHT FOR HEIGHT IN MONTSERRAT PRE-SCHOOL AGE CHILDREN, 2-3 YEAR OLDS.

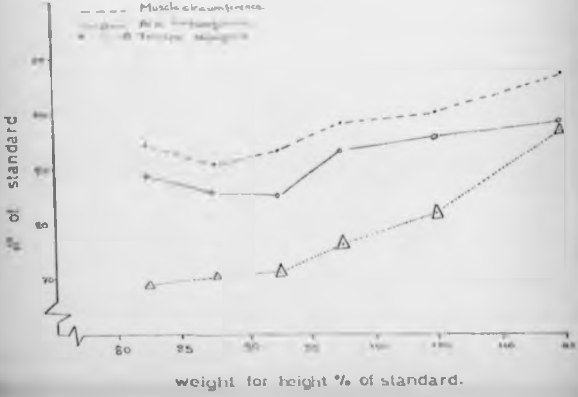
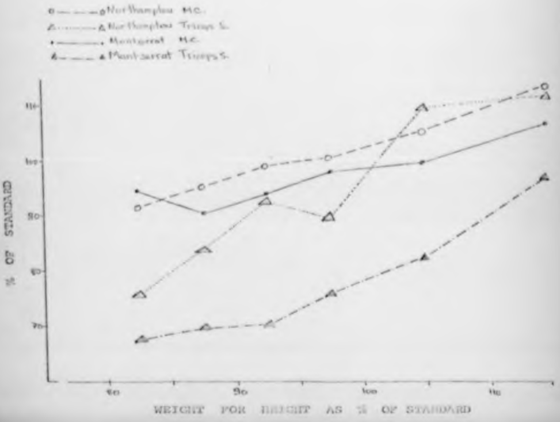


Figure IV. 5.

THE COMPARISON OF MUSCLE CIRCUMFERENCE AND TRICEPS SKINFOLD MEASUREMENTS OF 2-3 YEARS OLD NORTHAMPTON AND MONTSERRAT CHILDREN EXPRESSED IN RELATION TO THEIR WEIGHT FOR HEIGHT.



contribute much more to a fall in weight for height in Northampton than in Montserrat.

The assumption made in our analysis is that triceps skinfold measurement truly reflects not only the amount of subcutaneous fat but also the total body fat. This may not be true because Robson (1971) in an analysis of other Caribbean children has demonstrated a marked deficit in triceps skinfold thickness values in children who have not only an appropriate weight and height for their age but also a normal subscapular skinfold thickness. On the other hand, Piscopo (1962) compared three ethnic groups in America, namely Jewish, Italian and Negro boys and although Negro boys had the smallest skinfold thicknesses at all sites and ages their triceps skinfold thicknesses were found to be larger than the skinfolds taken at the scapula site. Malina (1966) also studied white and Negro children from Philadelphia, America and his findings revealed that Negro females had smaller triceps but larger subcapular skinfolds than Boston white females and slightly larger skinfolds than British white children (Hammond, 1955).

There has been controversy about the age related changes and the sex and racial differences in skinfold thickness during childhood. Several other workers studying other racial groups have reported different fat distributions from those found in Caucasian children

(Malina, 1972; Garn et. al., 1971).

Since we did not obtain a series of measurements of subcutaneous thickness at different sites in Montserrat children, we have no means of settling this problem but it must be recognized that the differences in skinfolds [illegible] origin with, for example, early limitations on growth leading to prolonged effects on the subsequent accumulation of fat in different areas of the body.

Despite these possible limitations in the significance of low triceps skinfold measurements it is nevertheless such a well established index in nutritional studies that it seemed appropriate to consider the changes so that we could define more objectively a cut-off point for triceps based not, for example, on a derived Caucasian value but on the relationship between the triceps skinfold thickness and weight for height deficits in our children.

F. Cut-off points for diagnosing malnutrition from arm measurements:

Since we have already agreed on taking 85 % of the standard for weight for height as a cut-off point for the diagnosis of wasting it seemed most appropriate to use this same cut-off point in deriving suitable limits for arm and muscle circumferences and triceps skinfold thickness measurements below which a child could be classified as wasted.

Table IV.17. summarises our choice of cut-off points on this basis. It is again apparent that Northampton and Montserrat cut-off points differ and that triceps values are very low in both populations. However a cut-off point in triceps values of 7 mm. corresponds to that arbitrarily suggested by Jelliffe and subsequently used by the Caribbean Food and Nutrition Institute.

Table IV.17

A table summarising our choice of cut-off points for assessing protein-energy malnutrition from arm measurements in Northampton and Montserrat.

Group	Age in years	Triceps		Arm C.		Muscle C.	
		% st.	mm.	% st.	cm.	% st.	cm.
Northampton	2-4	80.0	7.6	93.5	15.0	97.0	12.6
Montserrat	1-2	67.0	6.9	83.0	13.2	87.0	11.0
Montserrat	2-3	70.0	6.8	87.5	14.4	92.0	12.0

We initially attempted to define 3rd percentile limits for triceps measurements in normal children since attempts to obtain standard deviations are inappropriate because skinfold values have such a skewed distribution. Even a log transformation of skinfold measurements rarely results in a gaussian distribution so that this approach has not been used either. Accordingly the alternative method suggested above seems to have some value and leads [illegible] of 7 mm. [illegible] point for practical purposes.

However Figure IV.2. showed very clearly that to choose a value of 7 mm. for a reliable cut-off point would be unwise because only very small changes in skinfold thicknesses are observed over very large ranges in weight for height in our Caribbean children. Therefore while the accuracy of the skinfold measurement is approximately 7 – [illegible] ([illegible], 1973) this still means that the triceps skinfold is not a sensitive [illegible] of [illegible].

This is confirmed by the low correlation previously observed between skinfold thickness values and weight for height.

To choose measurements of arm circumferences may be more helpful. In Montserratian children cut-off points of 14 cm. seem appropriate but the value does [illegible] 14 cm. [illegible] the standard for children between 1 and 3 years and this again corresponds to the cut-off point originally suggested by Jelliffe who considered 85 % to be the 2 standard [illegible]. Jelliffe reported that other workers preferred 80 % as a limit but this has not gained acceptance and would represent a very substantial reduction, even below the logical cut-off point for Northampton children (Table IV.17) (Jelliffe and Jelliffe, 1969).

The error in measuring arm circumference has been found to be 3 % (Kondakis, 1969) i.e. approximately [illegible] proportion of [illegible] of 2 to 2.5 cm. between the 85 % and 100 % values for arm circumference measurements. We are therefore left with the conclusion that to use the arm circumference measurement would be appropriate in that it continues to reflect weight for height over the whole range but the error involved in the measurement reduces its usefulness as a sensitive measure.

Muscle circumference, although of obvious nutritional significance, [illegible] tion [illegible] it is derived from the arm and triceps values. The errors therefore limit the usefulness of muscle circumference values in particular.

G. A Comparison of the Various Cut off points:

Table IV. 18. [illegible] the proportion [illegible] group falling below the appropriate limit for each measurement.

As previously emphasized there are marked differences between the proportions of children with a weight for height deficit and height for age deficit. On the basis of the analysis shown in Figures IV.2. and IV.4. we would expect that the use of cut-off points for the muscle and arm circumference as well as for triceps skinfold thickness would yield proportions of children approximately equal to the proportion of children classified as malnourished on the basis of their weight for height. The results are shown in Table IV.18.

Equivalent proportions classified by each parameter were found in children below 3 years of age but the 3 and 4 year olds seemed to be categorised inappropriately with far more children specified as "malnourished" on the basis of limb measurements than expected on the basis of weight for height.

Careful inspection of Figures IV.[illegible] and IV.[illegible] suggests that the relationship between the actual relative cut-off points does indeed change with age. This observation implies that the 3 and 4 year olds' cut-off points for limb measurements should be reduced so that the cut-off point for the muscle circumference changes from 90 % to 85 % and the arm circumference from 85 % to 80 %. Similarly the cut-off point for skinfold thickness seems to be less appropriate in the older age groups.

The important point which emerges from this comparison is that the arm measurements are such that very small differences in the measurements lead to very large differences in the proportions of children which are classified as malnourished.

Therefore very small age dependent changes in the

Table IV. 18.

A comparison of the proportions of children falling below each cut-off point

All children under 5 years of age are included.

		Proportions of Children ([illegible])							
Age Groups in Months	Number of Children	Height/Age below % of standard	Weight/Age below % of standard.	Weight/Height below [illegible] of standard	Arm C./Age below % of standard		[illegible] below % of [illegible]	C/A.E.[illegible] below % of [illegible]	[illegible] below % [illegible]
0 - 5	85	22.14	3.4	6.9	5.8	0	35.2	[illegible]	2.3
6 -11	99	16.10	12.0	12.0	3.0	3.0	[illegible]	5.0	7.0
12 -23	207	36.30	17.2	8.3	11.3	3.7	15.8	6.2	11.5
24 -35	191	30.20	10.3	6.1	9.3	1.5	9.5	2.0	13.0
36 -47	231	19.00	8.1	1.7	0.2	2.5	9.8	2.8	12.5
48 -60	218	[illegible]	6.3	1.9	4.0	0	[illegible]	1.3	14.2

relationship between arm measurements and weight for height can markedly affect the appropriateness of a cut-off point. These observations also reinforce our conclusions that given the errors of measurement involved in muscle and arm circumference values these can only be considered as rather crude and insensitive indices of body wasting.

IV. 1. The Effects Of Systematic Errors In Height Measurements in the Nutritional Assessment of Pre-school Children:

In our percentile analyses of height measurement and in the choice of suitable cut off points for discriminating stunting in height we concluded that the accuracy with which we could measure height might prove important in determining the reliability of classifications based on height and the importance we should attach to specifying the particular instrument and technique used in measuring height (see Section III.6.).

The subsequent studies in Northampton and in London showed that the greatest errors were those associated with the use of one of our three home-produced measuring instruments. All the instruments whether made locally or not proved to be satisfactory in that they gave reproducible results.

This is important because provided the observers are well trained then the maximum errors involved in using different observers, different techniques and different instruments are only random errors which at maximum is 4 - 5 mm.

Although this error would involve a shift in the percentile calculation for example, from the 35th to the 43 rd percentile in the height of a 1 months old boy, this error only becomes important in longitudinal studies (see Section VII.5.D.). Repeated measurements or frequent monitoring of the height instruments would readily overcome this problem. Of more importance to this thesis is the question of whether the errors are important in cross-sectional studies.

Since these errors are randomised then in cross-sectional studies of populations we are concerned with the possibility of misclassifying children and either altering the [illegible] of children falling into a category, for example, below the cut-off point, or [illegible] the nutritional state of individual children. It should be readily apparent that an error of 5 mm. will not be a serious problem since in a 18 month old girl the standard deviation of expected height at this age amounts to as much as 2.5 cm. Since we use standard deviations as the yardstick for categorizing different degrees of stunting, the errors of measurement are clearly small in relation to the range of values found within each stunted group.

[illegible] if we consider systematic errors in measurement of height only one instrument is found "at fault". If we assume that the Holtain instrument gave the "true" result then one of our instruments, the Montserrat [illegible] Stick used for measuring height in children who are both able to stand and measured less than 84 cm. in height, gave a [illegible] systematic error of [illegible] cm., this [illegible]

1 cm. less than the Holtain.

When children measured by this Montserrat Toddler Stick are then assessed by calculating their height as a percentage of the standard then for example one child previously found to be 98.1 % of the standard is reclassified as 95.3 % if 1 cm is added to his height value. If we have a situation in which an appreciable proportion of children are measured as being between 94 and 95 % of the standard and therefore classified as "stunted" then they would have been considered "normal" when 1 cm is added to their height to overcome the systematic error in the Montserrat Toddler Stick. This is assessed in a group of Montserrat children aged 1 - 2 years all of whom had 1 cm. added to their height. Table IV.19. shows the effect of this adjustment on our assessment of stunting.

We may conclude from all our accuracy studies that there is no reason for nutritionists to insist on the purchase of expensive instruments such as the Holtain Stadiometer provided that there is one such instrument available with which a comparison can be made. The most important point is to establish initially whether there is any systematic error and subsequently to train the observers so that the random errors are as replicable as we found. There seem little evidence that the use of cheap instruments is meaningly avoided with high random errors.

Table [illegible]

An analysis of the effect of adding 1 cm. to the height of each child on the grouping of children in relation to the standard height for age.

	Proportions of children					
	Height for age as percentage of standard					
	100 % and above	99 - 95%	94 - 90%	89 - 85%	84 - 80%	below 79 %
Height as measured	14.0	39.8	34.4	8.7	1.9	0.9
1 cm. added to the observed height	[illegible]	41.7	29.6	5.3	0.9	0.9

Note that although there is a trend to reduce the numbers in the categories of "stunted" children the differences in this analysis did not achieve statistical significance.

χ^2 = P [illegible] 0.05.

IV. 4. The relationship between slow growth rates and the nutritional background of the children in Montserrat.

This thesis has concentrated on the anthropometric measures of nutritional state and the analyses have led to the conclusion that there are far fewer children who are wasted and near to a state of malnutrition requiring hospital admission than might be inferred from the usual classifications used for assessing malnutrition in the community. In these children, part of the weight deficit is accounted for by a slow growth rate and this factor could then lead to the conclusion that the children studied were merely showing an appropriate adaptive response to environmental influences and that there was no cause for concern. Before this conclusion can be accepted it is necessary to summarise information obtained on household feeding patterns in Montserrat at a time when we accepted the usual classifications of malnutrition and assessed the background of both randomly selected households and those of children specifically chosen on the basis of a rapid preliminary analysis as being malnourished, i.e. with a marked deficit in weight for age.

Table IV. 20. shows the foods eaten in the randomly selected households, the items being listed in the order of frequency with which they were consumed. It was shown that [illegible] staple [illegible] like [illegible], yam, sweet potatoes

Table [illegible]. 20.

[illegible] on Montserrat, [illegible] in [illegible] order of frequency with which they are eaten.

Food	Percentage of households [illegible] on any one [illegible]
Bread	80
Rice	67
Yam	43
B[illegible]	43
P[illegible]	40
Eggs	40
Salt Fish	33
Tinned Milk	33
Chicken	30
Sweet Potato	27
Be[illegible]	23
Irish Potato	23
Cooking Oil	23
Cooking margarine	23
Salami	20
Powdered milk substitutes	20
Breadfruit	17
Flour	17
Biscuit	[illegible]0
Co[illegible]	[illegible]

and bananas were frequently used together. Cereals were commonly eaten when available but most of the protein [illegible] to be derived from the additional [illegible] of [illegible] chicken, beef or peas, these being traditionally eaten with the main evening meal. Since these additional items were almost always purchased at a considerable cost, it seemed reasonable to look at the proportion of income spent on food in the 31 households visited. This is shown in Table IV.21. It is evident that almost a quarter of households spent most or all of their income on food and were therefore, in the absence of home produced [illegible], in a particularly vulnerable state if the price of the food suddenly increased or if the supplies proved inadequate because of shipping difficulties. It was observed that (Table IV.20) the flour was not generally available due to shipping complications and a major source of vegetable protein was therefore not obtainable on a reliable basis.

The high cost of animal protein and the reliance of the poorer households on cereals was emphasized when we compared the food consumption of additional households having "malnourished" children with the 31 households originally sampled.

The slow growing "malnourished" children had access to animal protein sources relatively infrequently and depended much more on the home-grown staple foods and the purchase of cereals.

TABLE 10.21.

An analysis of the number of randomly selected households spending different proportions of their income on food.

	Total No.	Percentage of total income spent on food							
		Less than 25 %		25-50%		50-75%		75-100%	
		No.	%	No.	%	No.	%	No.	%
Households	31	5	16	13	42	6	19	7	23

Table IV. 72.

An analysis of the income of randomly selected households i.e. "Normal Households", compared with the income of households selected as having underweight children i.e. "Malnourished Households".

Type of household	Total No. seen	Number and percentage of households at different levels of income. Dollars per month					
		0 - 150		151-300		Over 300	
		No.	%	No.	%	No.	%
Normal	31	12	39	12	39	7	22
Malnourished	8	7	88	1	12	0	0

The "malnourished" households were certainly poor with 7 of the 8 studied having a very low income indeed [illegible] with supplies of food costing more than in neighbouring islands as well as in the United Kingdom. Table IV.23. reinforces the fact that food was expensive in Montserrat. The results are explained on an energy basis rather than in terms of protein in order to emphasize the financial problem involved in obtaining food as such if these were not home-grown and had to be purchased.

Visits paid to the individual households with malnourished children clearly pointed out that several of these children were very short of food with often very little or no food in the households; several of the children had not had anything to eat by 4 p.m. in the afternoon on the day visited.

Thus it would be a mistake to assume that the vast majority of children in Montserrat were healthy and well fed. It would also seem wrong to imply that the slow growth rates, which we infer from our cross sectional study, were of no nutritional importance. The slow growth rates show that the children were responding to their environment and the fact that so few were truly wasted presumably reflects their remarkable capacity for adaptation and the body's ability to maintain lean body mass and compensate for inadequate food supplies. We cannot from our data assess which materials was chiefly responsible for

Table [illegible]

[illegible] cost in cents [illegible] of [illegible] country [illegible] food [illegible], and in the United Kingdom in [illegible].

Food	[illegible]	Jamaica[1] (E.C.)	United Kingdom[2]
Flour	13	9	10
Rice	15	19	24
Cooking Oil	17	12	19
Corn meal	19	6	23
Bread	20	38	21
Sweet potato	35	25	--
Peas	39	23	39
Cow's milk	41	67	61
Tinned milk	87	55	22
Egg	126	123	107
Beef	156	118	171
Chicken	167	140	137
Fish	220	109	164

1. Analysis provided by Dr. Ann Ashworth.
2. [illegible], 1969, [illegible]

the slow growth rates but food supplies did seem to be limited and any [illegible] deterioration in the provision of food would presumably lead to a situation where children were not only small for their [illegible] but wasted too.

Finally it must be recognized that at present we have very little information on the long-term effects of either wasting or slow growth rates. Follow up studies on children admitted to hospital with malnutrition demonstrate the importance of malnutrition [illegible] limiting a child's capacity to learn and progress in his mental development (Hertzig et. al., 1972). It is too early therefore to discuss "stunting" as an appropriate nutritional response without any long-term nutritional significance since we do not have enough information on the long-term effects of growth faltering or of a prolonged period with limited food supplies in childhood lead to a very slow increase in weight and height.

Our analysis does demonstrate, however that a major component of the weight deficit in the Caribbean is a deficit arising from a slowing in growth rates. A detailed analysis of the environmental factors involved in the slow growth rates such as those presented in detail by Morley et. al. (1968) for Nigeria was not possible in our survey but this lack of information does not signify that we considered the problem unimportant. The limitations on the time available for the survey were considerable but the household studies did highlight the environmental problems which seemed to be reflected in the slow growth rates.

SECTION V.

CONCLUSIONS

The analyses undertaken to assess the validity of our rapid survey of the nutritional status of children in Montserrat have led us to the following conclusions.

1. Rapid surveys such as that conducted in Montserrat can give meaningful and satisfactory information about the nutritional state of the community. Adequate planning is necessary but given an approach which takes into account the statistical needs such as obtaining sufficient data for analysis, it is possible to modify the design of surveys on the spot according to the local problems.

From our analysis, it is clear that there is a need to concentrate on obtaining data on the weights and heights of children although this does involve more time than, that involved in for example, the use of Quakstick (Arnhold, 1969). Devices such as the Quakstick are not adequate substitutes for weight and height measurements.

The technique of using coloured forms to differentiate the sexes and establishing measurement stations to maintain a flow pattern by measuring children who carry their own forms for the observer to record the measurement at each station allows the collection of anthropometric data to proceed in an orderly and fast manner. By organizing this flow pattern of measurement at least 1 child can be measured each minute.

2. The interpretation of our data was helped by including household visits in our survey. Qualitative information obtained from household surveys although inferior to quantitative measures of food intakes is nevertheless a valuable additional source of information.

3. Our survey demonstrated that the anthropometric values of the children in Montserrat were approximately equivalent to those from other Caribbean islands so that our subsequent detailed analysis is applicable to a much larger population, certainly for children in the West Indies and perhaps for many other countries elsewhere.

4. It was possible to show differences in the anthropometric measurements of boys and girls not only of school age but also of pre-school age. Thus the practice of combining the values for the two sexes may not always be correct. Grouping the values together, although convenient in terms of obtaining large numbers in each sub-group and comparing with only one standard may mask a differential effect on one of the sexes and these effects may be of social or biological origin.

5. It was concluded that the usual W.H.O. system

of assessing "malnutrition" classified many children as malnourished when the major reason for their weight deficit was their failure to grow. Thus most children were short for their age but had an appropriate weight for height.

6. The choice of standards with which to compare our data was critically examined and we concluded that the recent Dutch data provide more appropriate information on weight for height, particularly in relation to age, than those tables constructed by Jelliffe. The W.H.O. Monograph in fact presents information obtained on inadequate statistical grounds but the errors involved were shown to be small.

7. The need to emphasize height measurement in assessing nutritional state led to a critical analysis of the methods used for measuring heights, and it was concluded that in cross-sectional studies random errors in height measurement are likely to be small whatever the instrument provided observers are well trained. Differences between observers are not important and even the different methods used do not seem to produce appreciably different values.

8. Systematic errors in height can arise with home-made instruments and these need to be assessed by comparing locally manufactured (and therefore cheaper instruments) with a standard yardstick for example the Holtain instrument.

9. Attempts to show the relationship between weight, height and weight for height in strictly comparable terms led to the development of percentile figures from standards and the expression of all values in percentile terms. Although this method of expression seemed promising it soon became clear that this method is only applicable to longitudinal studies and the method also places far greater emphasis on the validity of the measurement and the appropriateness of the standards than can at present be justified. The percentile analysis is in any case too tedious and time consuming for routine use.

10. A more critical approach to the choice of cut-off points for weight, height and weight for height led to the choice of new values many of which coincided with those arbitrarily chosen by Jelliffe on the basis of practical experience. By using an approach based on the concept of normal distributions of anthropometric values it was shown that even fewer children were truly wasted than might have been considered on the basis of recent publications.

11. Triceps skinfold measurements in the Montserrat children were very much smaller than might be expected from their weight for height. This finding led to a comparison with data obtained from normal English children of the same age and it was confirmed that the arm measurements in Montserrat children were appreciably smaller than in Northampton children, even at equivalent weights for height.

12. The relationship between skinfold and muscle circumference measurements and weight for height was consistent with the hypothesis that subcutaneous fat was preferentially used as children wasted. However the degree to which skinfold measurements changed was so small in comparison with the error of measurement that the validity of using triceps skinfold measurements alone is questionable. Furthermore the errors involved in measuring arm circumference are such that it is likely that an appreciable proportion of malnourished children can, remain undiagnosed by this method.

13. Despite the problem with the arm measurements it was considered useful to develop cut-off points for these values also. In the abs-ence of relevant standard data cut-off points based on the equivalence of an arm circumference or triceps measurement with the cut-off point for weight for height were chosen and these also corresponded with the arbitrary ones first suggested by Jelliffe.

However, age-dependent differences in the relationship of arm measurrments to weight for height, as well as the errors, reduced the validity of choosing arm measurements as the only index of nutritional state.

14. Household surveys emphasized the need to remain cautious about the nutritional significance of slow growth rates. "Stunting" in height may not be important on a

short-term basis but we cannot conclude that slow growth is a satisfactory adaptive response. The analysis emphasizes the need to consider the nutritional significance of stunting which is still on a world-wide basis of major importance. To analyse this will require not only detailed knowledge of a child's age and height. There being little justification in this context for developing age independent indices, but there is a need for long term studies to assess the appropriateness of the choice of standards for height for use in developing countries.

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